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DESCRIPTION

Information Recording Medium, and Apparatus and Method for  
Recording Information to Information Recording Medium

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Technical Field

The present invention relates generally to a readable,  
writable data recording medium, and relates more particularly to a  
data recording medium for recording moving picture (video) data,  
still image data, audio data, and other types of multimedia data in  
data broadcasting and various other formats. The invention also  
relates to an apparatus and method for recording data to such a data  
recording medium.

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Background Art

Rewritable optical discs have had a maximum storage  
capacity of approximately 650 MB, but this limit has been pushed to  
several gigabytes by the introduction of DVD-RAM discs, a phase-  
change type of storage medium. Used in conjunction with practical  
implementations of MPEG (particularly MPEG-2), a digital AV data  
encoding standard, DVD-RAM is not limited to computer applications  
and will soon find widespread use as a recording and playback medium  
in the audio-video (AV) and even home entertainment industries.

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With the start of digital broadcasts in Japan it has  
become possible to multiplex and simultaneously transmit the video,  
audio, and data portions of plural programs to the MPEG transport  
stream ("MPEG\_TS" below). Digital broadcast recorders using hard  
discs or DVD media to record these programs are also available.

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These next-generation digital broadcast recorders  
typically record digital broadcasts in the original broadcast format

ATTACHMENT B

without converting the MPEG\_TS of the broadcast, and are expected to record AV data from an external line input using the MPEG\_TS so that the recorder does not need to internally handle both the MPEG program stream ("MPEG\_PS" below) and the MPEG\_TS.

5               However, because the current DVD logic standards (including the DVD-Video standard, DVD-Audio standard, DVD Video Recording standard, and DVD Stream Recording standard) use the MPEG\_PS for AV stream recording, MPEG\_TS to MPEG\_PS conversion (TS2PS conversion) is required in order to convert content recorded  
10           in the MPEG\_TS format, such as by the above-noted digital broadcast recorder, to the DVD-Video format, for example (see for example, JP2002-344888A).

              Converting a stream multiplexed to the MPEG\_TS to MPEG\_PS, however, involves a complex recalculation for decoder  
15           buffer management, the TS2PS conversion is time-consuming, and often involves re-encoding the elementary stream, resulting in degraded image quality and sound quality.

#### Disclosure of Invention

20           The present invention is directed to solving these problems and an object of the invention is to provide a data recording medium for recording an MPEG\_TS stream enabling fast, simple conversion when converting content recorded in the MPEG\_TS format to the MPEG\_PS format. A further object is to provide an  
25           apparatus and a method for recording data using the data recording medium of the invention.

              In a first aspect of the invention, provided is a recording medium for storing system stream including video elementary stream generated by encoding video information and audio  
30           elementary stream generated by encoding audio information with the

video elementary stream and the audio elementary stream being multiplexed. In the recording medium, the system stream is allowed to have a first format (TS) and a second format (PS). The first format (TS) has a structure for storing data segmented in first packets. The second format (PS) has a structure for storing data segmented in packs. The pack is larger than the first packet in size. The first packet stores segmented second packet. The second packet stores video information and audio information and includes at least one audio frame. The first format (TS) is allowed to have a constrained format used for converting the system stream from the first format (TS) to the second format (PS).

According to the constrained format, a predetermined number of first packets are grouped and managed as a multiplexing unit, and total data size of first packets managed in the multiplexing unit is smaller than data size of the pack, and the first one of complete audio frames in the multiplexing unit is the first one of audio frames in a payload of the second packet.

According to the constrained format, the video elementary stream and the audio elementary stream may be multiplexed to the system stream in the same order as a multiplexing order in the second format (PS) that is converted.

The elementary stream may be encoded in an encoding method which is allowed for both the first format and the second format.

The system stream may include encode information that indicates whether or not the first one of complete audio frames in the multiplexing unit is the first one of audio frames in a payload of the second packet. The encode information may be also included in management information for managing data stored in the recording medium.

In a second aspect of the invention, provided is an information recording apparatus for encoding video information and audio information to system stream and recording the system stream to a recording medium.

5           The system stream is allowed to have a first format (TS) and a second format (PS). The information recording apparatus includes a first encoding section operable to encode video information and audio information in a predetermined encoding manner according to the first format (TS) to generate video elementary  
10           stream and audio elementary stream; a second encoding section operable to perform system-encoding by multiplexing the video elementary stream and the audio elementary stream to generate the system stream according to the first format (TS); and a control  
15           section operable to control the first encoding section and the second encoding section.

          The first format (TS) is allowed to have a constrained format used for converting the system stream from the first format (TS) to the second format (PS).

          The control section controls the first and second  
20           encoding section so that each encoding is done according to the constrained format. The first format (TS) has a structure for storing data segmented in first packets. The second format (PS) has a structure for storing data segmented in packs. The pack is larger  
25           than the first packet in size. The first packet stores segmented second packet, the second packet stores video information and audio information and includes at least one audio frame.

          According to the constrained format, a predetermined number of first packets are grouped and managed as a multiplexing unit, and total data size of first packets managed in the  
30           multiplexing unit is smaller than data size of the pack. The first

one of complete audio frames in the multiplexing unit is the first one of audio frames in a payload of the second packet.

5 In a third aspect of the invention, provided is an information recording method including encoding video information and audio information to system stream and recording the system stream to a recording medium.

10 The system stream is allowed to have a first format (TS) and a second format (PS). The first format (TS) is allowed to have a constrained format used for converting the system stream from the first format (TS) to the second format (PS). The first format (TS) has a structure for storing data segmented in first packets, the second format (PS) has a structure for storing data segmented in packs, the pack is larger than the first packet in size. The first packet stores segmented second packet, the second packet stores  
15 video information and audio information and includes at least one audio frame.

20 The information recording method includes encoding video information and audio information in a predetermined encoding method according to the constrained format (TS) to generate video elementary stream and audio elementary stream; performing system-encoding by multiplexing the video elementary stream and the audio elementary stream according to the constrained format (TS) to generate the system stream; and grouping and managing a predetermined number of first packets as a multiplexing unit.

25 Total data size of first packets managed in the multiplexing unit is smaller than data size of the pack. The first one of complete audio frames in the multiplexing unit is the first one of audio frames in a payload of the second packet.

30 According to the present invention, video information can be recorded so that, according to the constrained format, the

first one of complete audio frames in the Multiplexing Unit is the first audio frame in the payload of PES packet in the Multiplexing Unit. Hence, during conversion from the recorded video information to VOB of DVD-Video, it is not necessary to calculate and obtain newly time stamp information specified by DVD standard, thereby resulting in simple and high-speed processing.

#### Brief Description of Drawings

Fig. 1 is a schematic diagram showing a DVD recording apparatus and an exemplary interface between the DVD recording apparatus and other components used in conjunction therewith.

Fig. 2 is a block diagram of the drive apparatus of a DVD recorder.

Fig. 3A illustrates a contiguous area on the disc, and Fig. 3B is a graph illustrating the data accumulation in a track buffer.

Fig. 4 is a block diagram of a DVD recorder having a semiconductor memory card and hard disk drive.

Figs. 5A and 5B show a data region of a disc and data structure of the disc, respectively.

Figs. 6A and 6B show the logical data space of the disc.

Fig. 7 shows the disc directory and file structure.

Fig. 8 shows the structure of a video object.

Fig. 9 shows the MPEG system stream.

Figs. 10A to 10C show the MPEG transport stream (MPEG\_TS).

Figs. 11A to 11C show the MPEG program stream (MPEG\_PS).

Figs. 12A to 12D show a TS packet.

Figs. 13A to 13C2 shows a PAT table.

Figs. 14A to 14C show the arrangement of video objects

on disc.

Figs. 15A and 15B show the data structure of video management information.

5 Figs. 16A and 16B show the data structure of video management information.

Fig. 17 shows the relationship between an object, object information, and PGC information in the video management information.

Fig. 18 is a block diagram showing the functional configuration of a playback apparatus.

10 Fig. 19 is a block diagram showing the functional configuration of a recording apparatus.

Fig. 20 is a block diagram showing the configuration of a data recording and reproducing apparatus according to the present invention.

15 Fig. 21 shows the structure of a self-encoding stream.

Figs. 22A and 22B describes the packet transfer time interval.

Fig. 23 describes a storage method for a User Private packet.

20 Fig. 24 describes a storage method for a User Private packet.

Fig. 25 describes a storage method for a User Private packet.

25 Fig. 26 describes a storage method for a User Private packet.

Figs. 27A to 27H described conversion of an MPEG\_TS to an MPEG\_PS.

Figs. 28A to 28G show an encoding method for an MPEG\_TS enabling easy conversion to an MPEG\_PS.

30 Fig. 29 shows conversion to a DVD Video format (NTSC).

Fig. 30 shows conversion to a DVD Video format (PAL).

Fig. 31 shows the internal data structure of a User Private packet.

5 Fig. 32 shows the correlation between an MPEG\_TS encoded for easy conversion to an MPEG\_PS and the MPEG\_PS after conversion.

Fig. 33 is a block diagram of the encoder of a data recording apparatus according to the present invention.

10 Fig. 34 shows differences in processes for converting from a self-encoded MPEG\_TS to DVD formats due to differences in system encoding.

Fig. 35 shows the Tip packet data structure.

Fig. 36 shows the adaptation field data structure.

Fig. 37 shows the Data\_ID data structure.

Fig. 38 shows the display\_and\_copy\_info data structure.

15 Fig. 39 shows the encode\_info data structure.

Fig. 40 shows the PES\_info data structure.

Fig. 41 shows the MakersPrivateData data structure.

Fig. 42A shows PID of the Tip packet.

Fig. 42B shows the stream\_type of Tip packet.

20 Fig. 43 shows field values of the PES packet header in a Constrained SESF stream.

Fig. 44 shows the PES\_extension\_flag and PES\_header\_data\_length in a Constrained SESF stream.

25 Fig. 45 shows an example of an MPEG\_TS self-encoded such that it does not satisfy T\_STD model.

Figs. 46A and 46B show an example of an MPEG\_PS converted from a MPEG\_TS such that the MPEG\_PS does not satisfy the P\_STD model.

Fig. 47 shows SCR calculation.

30 Fig. 48 shows the elementary stream attributes of a



Constrained SESF when encode\_condition = 11b.

Fig. 49 shows the elementary stream attributes of a Constrained SESF when encode\_condition = 01b.

5 Fig. 50 shows the stream structure of a format conforming to the DVD Video standard.

Fig. 51 shows the structure of PCI data in NV\_PCK.

Fig. 52 shows the structure of PCI\_GI data in NV\_PCK.

Fig. 53 shows the structure of DSI data in NV\_PCK.

Fig. 54 shows the structure of DSI\_GI data in NV\_PCK.

10 Fig. 55 shows the structure of SML\_PBI data in NV\_PCK.

Fig. 56 shows the structure of SYNCI data in NV\_PCK.

Fig. 57 shows the stream structure of a format conforming to the DVD Video Recording standard.

15 Fig. 58 is a flow chart of the TS packet (RD\_PCK) conversion process.

Fig. 59 is a flow chart of the TS packet (V\_PCK, A\_PCK) conversion process.

Fig. 60 shows a part of the data structure of the pack header in an MPEG-2 program stream pack.

20 Fig. 61 shows a DVD format system header.

Fig. 62A shows the structure of a packet header stored in RDI\_PCK.

Fig. 62B shows the structure of a packet header stored in RDI\_PCK.

25 Fig. 63 shows a part of the data structure of the packet header in an MPEG-2 program stream packet.

Fig. 64 shows the structure of an AC-3 standard private header in the DVD format.

30 Figs. 65A and 65B show converting a Constrained SESF to an MPEG\_PS for a video pack.

Figs. 66A and 66B show converting a Constrained SESF to an MPEG\_PS for an audio pack.

Fig. 67 is a table of audio bit rates allowed by the Constrained SESF, and the maximum payload length stored to one audio PES packet for AC-3 and MPEG-1 Audio at the corresponding bit rates.

Fig. 68 is a flow chart of overall TS2PS conversion process.

Fig. 69 is a flow chart of initialization process in the TS2PS conversion process.

Fig. 70 is a flow chart of the capsule unit process in the TS2PS conversion process.

Fig. 71 is a flow chart of the pack unit process.

Fig. 72 is a flow chart of the SCR calculation process.

Fig. 73 is a flow chart of the pack header process.

Fig. 74 is a flow chart of the packet header process.

Fig. 75 is a flow chart of the stream ID process.

Fig. 76A is a flow chart of the video PES packet leading process.

Fig. 76B is a flow chart of the video PES packet non-leading process.

Fig. 77A is a flow chart of the audio PES packet leading process.

Fig. 77B is a flow chart of the audio PES packet non-leading process.

Fig. 78 is a flow chart of the payload process.

Fig. 79 is a flow chart of the padding packet process.

Fig. 80 shows the Constrained SESF stream format.

Fig. 81 shows the data structure of an MPEG standard PES packet.

Fig. 82 shows a method of generating NV\_PCK data.

Fig. 83A shows efficiency multiplexing method using Multiplexing Unit with audio frames aligned.

Fig. 83B shows efficiency multiplexing method using Multiplexing Unit with I-picture aligned in the lead.

5 Fig. 84A shows encode conditions related to the order of video presentation fields in Constrained SESF (when satisfying DVD-Video standard).

Fig. 84B shows encode conditions related to the order of video presentation fields in Constrained SESF (when not satisfying  
10 DVD-Video standard).

Fig. 85 is a flow chart of the recording process according to Constrained SESF provided with constraints for a top field and a bottom field.

Fig. 86 is a flow chart of the end recording process.

#### 15 Best Mode for Carrying Out the Invention

A DVD disc, DVD recorder, and DVD player are described with reference to the accompanying figures in the sequence shown below as preferred embodiments of a data recording medium, recording  
20 apparatus, and playback apparatus according to the present invention.

Key points of the present invention are described particularly in the following section 8, outline of the invention, and section 9, detailed embodiments of the invention. While the relationship to the present invention may vary, all of the following  
25 describe various aspects of the invention.

1. Outline of the DVD recorder system
2. Function outline of the DVD recorder
3. Outline of the DVD disc
4. Outline of reproduced AV data
- 30 5. AV data management information and playback control

6. Basic operation of the playback function
7. Basic operation of the recording function
8. Outline of the invention
9. Detailed embodiments of the invention

5 The following terminology is used below.

"TS2PS conversion" refers to converting the MPEG transport stream (MPEG\_TS) to the MPEG program stream (MPEG\_PS).

"DVD format" refers to both the DVD-Video standard format and the DVD-Video Recording standard format, each being an  
10 MPEG\_PS implementation.

#### 1. Outline of the DVD recorder system

Fig. 1 shows a typical DVD recorder in relation to other systems and devices used with the DVD recorder.

15 As shown in Fig. 1 a DVD, which is a type of optical disc, is loaded to the DVD recorder for recording video data to the disc and reproducing video data from the disc. A remote control device is typically used to operate the DVD recorder.

The video data input to the DVD recorder could be an  
20 analog signal or a digital signal with analog broadcasts exemplary of analog signals and digital broadcasts exemplary of digital signals. Generally speaking, analog broadcasts are received and demodulated by the receiver built in to a television, and input as an NTSC or other analog video signal to the DVD recorder for  
25 recording. Digital broadcasts are demodulated to a digital signal by the digital broadcast receiver (set-top box (STB)) input to the DVD recorder for recording.

Video data recorded to a DVD is reproduced by the DVD recorder and externally output. Like the video input, video output  
30 may be an analog signal or digital signal. Analog signals are input

directly to the television. Digital signals are passed through the STB and converted to an analog signal, which is then input to the television for video presentation.

5 Video data may also be recorded to and reproduced from a DVD by a device other than a DVD recorder, such as a DVD camcorder or personal computer. A DVD disc storing video data recorded by a device other than a DVD recorder will also be reproduced by the DVD recorder when loaded therein.

10 It should be noted that audio data is normally associated with the video data of an analog broadcast or digital broadcast, and this audio data is likewise recorded and reproduced by the DVD recorder.

15 Furthermore, the video data is generally moving picture data, but could also include still images such as when a still image (photograph) is captured using the snapshot function of a DVD camcorder.

IEEE 1394, ATAPI, SCSI, or other standard could be used for the digital interface between the STB and DVD recorder.

20 It should also be noted that an NTSC signal is referred to above as the type of component video signal passed between the DVD recorder and television, but a component signal sending separate luminance and color difference signals could be used. Furthermore, changing the interface for transmitting video between AV components and televisions from an analog interface to a digital interface such as DVI is currently being researched, and we anticipate that a  
25 digital interface can also be used to connect DVD recorders and televisions.

## 2. Function outline of the DVD recorder

30 Fig. 2 is a function block diagram of a DVD recorder.

The drive device has an optical pickup 101 for reading data from a DVD-RAM disc 100, an ECC (error correction code) processor 102, track buffer 103, switch 104 for changing track buffer 103 input and output, an encoder 105, and a decoder 106.

5           As shown in the figure data is recorded to the DVD-RAM disc 100 with the smallest recording unit being one sector (= 2 KB). Furthermore, 16 sectors equal 1 ECC block, and the ECC processor 102 applies error correction processing using ECC block units.

10           The DVD recorder could also use semiconductor memory cards or hard disk drives in addition to DVDs as data storage media. Fig. 4 is a block diagram of a DVD recorder having a semiconductor memory card and hard disk drive.

15           It should also be noted that 1 sector could be 512 bytes, 8 KB, or other size. The ECC block could also contain 1 sector, 16 sectors, 32 sectors, or other configuration. It is expected that the sector size and number of sectors in each ECC block will also increase as the recordable data capacity increases.

20           The track buffer 103 is a buffer for recording AV data at a variable bit rate (VBR) in order to record AV data more efficiently to the DVD-RAM disc 100. The DVD-RAM disc 100 write rate ( $V_a$ ) is a fixed rate but the bit rate ( $V_b$ ) of the AV data varies according to the complexity of the AV content (images in the case of video content). The track buffer 103 is used to absorb this bit rate difference.

25           In order to use this track buffer 103 even more effectively, the AV data can be distributively recorded to the disc 100. This is further described with reference to Figs. 3A and 3B.

30           Fig. 3A shows the disc address space. As shown in Fig. 3A, continuous playback of the AV data is enabled when the AV data is recorded to separate contiguous spaces [a1, a2] and [a3, a4] by

supplying data accumulated in the track buffer to the decoder 106 while seeking from a2 to a3. The change in the amount of data stored to the track buffer at this time is shown in Fig. 3B.

When reading starts at address a1, the AV data is input from time t1 to the track buffer 103 and data output from the track buffer 103 also starts. Data then accumulates in the track buffer 103 at the rate (Va-Vb), that is, the difference between the input rate (Va) to the track buffer 103 and the track buffer output rate (Vb). This continues until the search area reaches a2, that is, until time t2. If the data accumulated in the track buffer 103 during this time is B(t2), data can be supplied to the decoder 106 by gradually depleting the data B(t2) accumulated in the track buffer 103 from time t2 to the time t3 at which reading from the address a3 begins.

In other words, a continuous supply of AV data can be maintained during seek operations insofar as at least a specified amount of data ([a1, a2]) has been read before the seek operation starts.

The size of the contiguous area required to enable continuous AV data output when converted to an ECC block count (N\_ecc) is shown by the following equation:

$$N_{ecc} = Vb \cdot Tj / ((N_{sec} \cdot 8 \cdot S_{size}) \cdot (1 - Vb/Va))$$

where N\_sec is the number of sectors in an ECC block, S\_size is the sector size, and Tj is the seek performance (maximum seek time).

A defective sector could also occur in a contiguous area. The required size of the contiguous area in this case is shown by the following equation:

$$N_{ecc} = dN_{ecc} + Vb \cdot Tj / ((N_{sec} \cdot 8 \cdot S_{size}) \cdot (1 - Vb/Va))$$

where dN\_ecc is the size of the allowed defective sector, and Ts is the time needed to skip the defective sector within the contiguous

area. This equation also returns the size of the contiguous area as the number of ECC blocks.

The above example is described using reading data from a DVD-RAM disc, that is, data playback, by way of example, but it will be obvious that writing, that is, recording, data to the DVD-RAM disc can be handled in the same way.

Continuous data playback and recording can thus be achieved with a DVD-RAM disc even when the AV data is recorded to separate recording areas on the disc insofar as the data is recorded in blocks of a specific size or more. These contiguous areas are referred to as Contiguous Data Areas (CDA) in DVD terminology.

### 3. Outline of the DVD disc

Figs. 5A and 5B show the physical structure and a plan view of a DVD-RAM, i.e., a recordable optical disc. DVD-RAM discs are typically housed in a cartridge for loading to a DVD recorder. The purpose of the cartridge is to protect the disc. The DVD-RAM disc can, however, be loaded directly to the DVD recorder without being housed in a cartridge if the recording surface can be protected in some other way.

DVD-RAM discs are recorded using a phase-change recording technique. Data on the disc is managed by sector unit, and addresses are added for data access. Groups of 16 sectors are used for error correction, have an error correction code added thereto, and are referred to as ECC blocks.

Fig. 5A shows the recording area of a DVD-RAM disc, i.e., a recordable optical disc. As shown in the figure, a DVD-RAM disc has a lead-in area at the inside circumference, a lead-out area at the outside circumference, and a data area between the lead-in and lead-out areas.



Reference signals for stabilizing the servo when accessing the disc with the optical pickup, and an ID signal for distinguishing a DVD-RAM disc from other types of media, are recorded to the lead-in area.

5           The same reference signals are also recorded to the lead-out area.

          The data area is segmented into sectors (each 2048 bytes) as the smallest access unit. The data area is also segmented into a plurality of zones in order to apply a rotational control  
10       technique known as Zone Constant Linear Velocity (Z-CLV) during recording and playback.

          Fig. 5A shows plural zones formed concentrically on the DVD-RAM disc. In this example the DVD-RAM disc is divided into 24 zones, labelled zone 0 to zone 23. The rotational angular velocity  
15       of the DVD-RAM is set differently in each zone such that it increases in proximity to the inside circumference and is constant while the optical pickup accesses data in the same zone. This increases the recording density of the DVD-RAM and enables easier rotational control during recording and playback.

20           Fig. 5B shows the lead-in area, lead-out area, and zones 0 to 23 concentrically arranged in Fig. 5A when viewed in a line through the disc radius.

          The lead-in area and lead-out area each include a defect management area (DMA). The defect management area is for recording  
25       position information indicating the location of a sector containing a defect, and substitute sector position information indicating in which substitute area the sector substituted for the defective sector is located.

          Each zone includes a user area between a substitute area  
30       and an unused area. The user area is the area that can be used by

the file system as a recording area. The substitute area is the area substitutionally used when there is a defective sector. The unused area is an area not used for data recording, and is approximately two tracks wide. The sector address is recorded to the same position in adjacent tracks within each zone, but with Z-CLV the sector address is recorded to a different position in tracks adjacent to the zone boundary. This unused area is therefore provided to prevent sector address detection errors in tracks adjacent to the zone boundary.

There are, therefore, sectors not used for data recording at the zone boundaries. A logical sector number (LSN) is therefore assigned to each physical sector in the user area of a DVD-RAM disc sequentially from the inside circumference in order to continuously identify only those sectors used for data recording.

Fig. 6 shows the logical data space of a DVD-RAM disc comprising logical sectors. The logical data space is called the "volume space" and is used to record user data.

Data recorded in the volume space is managed with a file system. More specifically, a group of sectors storing data is a "file," and volume structure information managing a group of files as a "directory" is recorded to the beginning and end of the volume area. The UDF file system is used in the present embodiment and conforms to ISO 13346.

The above-noted group of sectors is not necessarily contiguous within the volume space, and can be split into separate parts. Of the sectors constituting each file, the file system therefore manages each group of contiguous sectors in the volume space as an extent, and manages each file as a set of related extents.

Fig. 7 shows the structure of a directory and file

recorded to DVD-RAM. Below the root is the VIDEO\_RT directory, and below VIDEO\_RT are the various object files containing the playback data and a VIDEO Manager file containing management information such as the playback sequence and various attributes.

5                Objects are data structures conforming to MPEG standards, and include PS\_VOB, TS1\_VOB, TS2\_VOB, AOB, POB, and MNF (Manufacturer's Private Data).

              PS\_VOB, AOB, and POB are MPEG program streams (PS), and TS1\_VOB and TS2\_VOB are MPEG transport streams (TS). The program  
10 stream has a data structure designed for storing AV data to package media. The transport stream has a data structure intended for communications media.

              PS\_VOB, TS1\_VOB and TS2\_VOB are objects of primarily video data but containing both video data and audio data. In  
15 principle, TS1\_VOB objects are encoded by the DVD recorder with an explicitly managed internal picture structure. TS2\_VOB objects are encoded externally to the DVD recorder, and part of the internal picture structure and data structure is unknown.

              Typically, TS1\_VOB objects are externally input analog  
20 video signals encoded by the DVD recorder to the transport stream, and TS2\_VOB objects are externally input digital video signal objects recorded directly to disc without further encoding by the DVD recorder. That is, when a DVD recorder records digital broadcasting, TS2\_VOB is generally used.

25                AOB and POB are MPEG program streams. AOB objects contain primarily audio data, and POB objects contain primarily still images.

              The MNF (Manufacturer's Private Data) block is used to store information specific to a particular manufacturer.

30                "Primarily video data" and "primarily audio data" above

indicate that a high bit rate is allocated. VOB are used in video and similar applications, and AOB are used in music applications.

#### 4. Outline of reproduced AV data

Fig. 8 shows the structure of MPEG data recorded as AV objects to a DVD.

As shown in Fig. 8, the video stream and audio stream are segmented and multiplexed. The MPEG standard refers to the multiplexed streams as the system stream. In the case of DVD, a system stream containing DVD specific settings is called a VOB (Video Object). The segmentation units are called packs and packets, and are approximately 2 KB in size.

The video stream is encoded according to the MPEG standard, variable bit rate compressed such that the bit rate is increased in complex images such as images containing much movement. The pictures in an MPEG stream are encoded as I-pictures, P-pictures, or B-pictures. I-pictures are spatially compressed and complete within each frame. P-pictures and B-pictures are temporally compressed using inter-frame correlations. A series of pictures including at least one I-picture is referred to as a Group of Pictures (GOP) in MPEG. A GOP is the access point for fast play and other special play modes, which are made possible by the presence of at least one intra-frame compressed I-picture.

In addition to using MPEG audio, the audio stream of a DVD can be encoded using AC-3, LPCM, or other encoding technique.

As also shown in Fig. 8 the Video Object Unit (VOBU) is the data unit multiplexing the video data of a GOP with the associated audio data. Video management data can also be included in a VOB as header information.

A program stream (PS) and transport stream (TS) are

included in the system stream described with reference to Fig. 8. As noted above, the program stream has a data structure intended for package media and the transport stream data structure is intended for communications media.

5                Fig. 9 shows the concept of the program stream and transport stream data structures.

              The program stream comprises fixed length packs that are the smallest unit for data transfer and multiplexing. Each pack contains one or more packets. Both packs and packets comprise a header part and a data part. The data part is referred to as the payload in MPEG. For compatibility with the sector size, the fixed length of a pack in DVD is 2 KB. A pack can contain multiple packets, but because packs storing DVD video and audio contain only one packet, 1 pack equals 1 packet except in special cases.

15              The data transfer and units for multiplexing of the transport stream comprises fixed length TS packets. TS packet size is 188 bytes for compatibility with ATM transmissions, a communications standard. One or more TS packets form a PES packet.

              PES packets are a concept common to both the program stream and transport stream, and the data structure is the same. Packets stored in program stream packs directly form PES packets, and a group of one or more transport stream TS packets form a PES packet.

25              The PES packet is the smallest encoding unit and stores video data and audio data with common encoding. More specifically, video data and audio data encoded with different coding methods are not present in a same PES packet. However, if the coding method is the same, it is not necessary to ensure the picture boundaries and audio frame boundaries. As shown in Fig. 9 one frame is stored to plural PES packets, and plural frames may be stored to one PES

30

packet.

Figs. 10A to 10C and Figs. 11A to 11C show the data structures of the transport stream and program stream.

5 As shown in Figs. 10A to 10C and Figs. 12A to 12D, each TS packet comprises a TS packet header, adaptation field, and payload. The TS packet header stores a Packet Identifier (PID) whereby the video, audio, or other stream to which the TS packet belongs can be identified.

10 The Program Clock Reference (PCR) is stored to the adaptation field. The PCR is the reference value for the system time clock (STC) of the device decoding the stream. The device typically demultiplexes the system stream based on the PCR timing, and then reassembles the video stream and other streams.

15 The Decoding Time Stamp (DTS) and Presentation Time Stamp (PTS) are stored to the PES header. The DTS indicates the decoding timing of the picture or audio frame stored to the PES packet, and the PTS indicates the presentation timing of the video or audio output.

20 It should be noted that the PTS and DTS need not be written to every PES packet header. Decoding and output are possible insofar as the PTS and DTS are written to the header of the PES packet where the first data of the I-picture is stored.

The TS packet structure is shown in detail in Figs. 12A to 12D.

25 As shown in Figs. 12A to 12D the adaptation field stores the PCR and a random access presentation flag. This flag indicates whether data that is at the beginning of the video or audio frame and can be used as an access point is stored in the corresponding payload. In addition to the above-noted PID, the TS packet header  
30 also stores a unit start presentation flag indicating the beginning

of a PES packet, and adaptation field control data indicating whether an adaptation field follows.

Figs. 11A to 11C show the structure of packs in the program stream. The pack contains the SCR in the pack header and a stream\_id in the packet header of packets stored in the pack. The SCR is effectively identical to the transport stream PCR, and the stream\_id to the PID. The PES packet data structure is also the same as in the transport stream, and the PTS and DTS are stored in the PES header.

One major difference between the program stream and transport stream is that the transport stream allows for multiple programs. That is, in terms of program units, the program stream can carry only one program but the transport stream can simultaneously transmit multiple programs. This means that the playback device must be able to identify the video streams and audio streams constituting each program carried in the transport stream.

Figs. 13A to 13C2 shows the PAT table and PMAP table used to transmit structure information for the audio stream and video stream of each program. As shown in Figs. 13C1 and 13C2 the PMAP table stores information relating to the combination of video and audio streams used in each program, and the PAT table stores information correlating programs and PMAP tables. The playback device can therefore reference the PAT table and PMAP table to detect the video and audio streams for the program to be output.

How the program stream packs and transport stream TS packets described above are arranged on the disc is described next with reference to Figs. 14A to 14C.

As shown in Fig. 14A there are 32 sectors in an ECC block.

As shown in Fig. 14B, the packs (PS Packs) forming a

video object (PS\_VOB) of a program stream type are located at the sector boundaries. This is because the pack size and sector size are both 2 KB.

5 Video objects (TS1\_VOB, TS2\_VOB) of the transport stream type, however, are 8 KB units and are therefore contained in the ECC block. Each 8 KB unit contains an 18 byte header area and 43 TS packets containing Arrival Time Stamp (ATS) information in the data area. The ATS information is data generated and added by the DVD recorder, and indicates the timing at which the packet was received  
10 by the DVD recorder from an external source.

It should be noted that an MPEG\_TS storage format continuously recording combinations of fixed-byte length ATS and MPEG\_TS packets is also possible as shown in Fig. 14C.

## 15 5. AV data management information and playback control

Figs. 15A to 15B and Figs. 16A to 16B show the data structure of the video management information file (Video Manager) shown in Fig. 7.

The video management information includes object  
20 information describing such management information as where objects are recorded on disc, and presentation control information describing the playback sequence of the objects.

Fig. 15A shows an example in which the objects recorded to the disc include PS\_VOB#1 - PS\_VOB#n, TS1\_VOB#1 - TS1\_VOB#n, and  
25 TS2\_VOB#1 - TS2\_VOB#n.

As shown in Fig. 15A a PS\_VOB information table, TS1\_VOB information table, and TS2\_VOB information table are separately recorded according to the object types. Each of these tables stores VOB information for each object.

30 The VOB information includes general information about



the corresponding object, object attribute data, an access map for converting the object playback time to a disc address value, and management information for the access map. The general information includes identification information for the corresponding object and  
5 object recording time. The attributes include video stream attributes (V\_ATR) such as the video stream coding mode, the number of audio streams (AST\_Ns), and audio stream attributes (A\_ATR) such as the audio stream coding mode.

There are two reasons why an access map is required. The  
10 first is so that the playback path information avoids directly referencing object recording positions based on a sector address value, for example, and instead can indirectly reference object locations based on the object playback time. Object recording positions can change with RAM media as a result of editing the  
15 object, for example. This increases the amount of playback path information that must be updated if the playback path information references object recording positions directly based on the sector address. If the objects are referenced indirectly based on the playback time, however, it is not necessary to update the playback  
20 path information and only the access map needs to be updated.

The second reason is that the audio stream typically has two reference bases, the time base and data (bit stream) base, but the correlation therebetween is not complete.

For example, using a variable bit rate (a method of  
25 changing the bit rate according to the complexity of the image) is becoming the norm with MPEG-2 Video, an international standard for video stream encoding. In this case there is no proportional relationship between the amount of data from the stream start and playback time, and random access based on the time base is therefore  
30 not possible. An access map is used to resolve this problem by

converting between the time base and data (bit stream) base.

As shown in Fig. 15A, the presentation control information includes a user-defined playback path information table, original playback path information table, and title search pointer.

5 As shown in Fig. 16A there are two types of playback paths data: originally defined playback path information generated automatically by the DVD recorder to describe all objects recorded during object recording, and user-defined playback path information enabling a user to freely define a particular playback sequence. The  
10 playback path information is uniformly referred to as Program Chain Information (PGC information) on a DVD, the user-defined playback path information is referred to as the U\_PGC information, and the original playback path information as the O\_PGC information. The U\_PGC information and O\_PGC information are tables listing the cell  
15 information describing the cells in the object playback period. The object playback period indicated by the O\_PGC information is called an original cell (O\_CELL), and the object playback period indicated by the U\_PGC information is called a user cell (U\_CELL).

20 A cell indicates the object playback period using the object playback start time and playback end time; the playback start and end times are converting by the access map described above to the actual location where the object is recorded on disc.

As shown in Fig. 16B, a cell group indicated by the PGC information defines a continuous playback sequence reproduced  
25 sequentially according to the order of entries in the table.

Fig. 17 shows a specific relationship between objects, cells, PGC, and access map.

As shown in Fig. 17 the original PGC information 50 contains at least one cell information entry 60, 61, 62, 63.

30 Each cell information entry defines the object to

reproduce as well as the object type, and object playback period. The order of the cell information entries in the PGC information 50 defines the playback sequence of the objects defined by each cell when the objects are reproduced.

5           Each cell information entry (cell information 60, for example) includes a Type 60a indicating the type of specific object, an Object ID 60b identifying a particular object, and a start presentation time Start\_PTM 60c and end presentation time End\_PTM 60d in the object on the time base.

10           During data playback the cell information 60 is sequentially read from the PGC information 50, and the objects specified by each cell are reproduced for the playback period defined by the cell.

          The access map 80c converts the start and end time  
15 information contained in the cell information to the object address on disc.

          This access map is the map information described above and is generated and recorded when the objects are recorded. The picture structure of the object data must be analyzed in order to  
20 generate the map. More specifically, it is necessary to detect the I-picture location shown in Fig. 9, and detect the PTS and other time stamp information, that is, the I-picture playback time shown in Figs. 10A to 10C and Figs. 11A to 11C.

          Problems occurring when generating the PS\_VOB, TS1\_VOB,  
25 and TS2\_VOB map information are described next.

          As described with reference to Fig. 1, the PS\_VOB and TS1\_VOB are primarily generated by the DVD recorder encoding a received analog broadcast to an MPEG stream. The I-picture and time stamp information is therefore auto-generated by the DVD recorder,  
30 the internal data structure of the stream is known to the DVD

recorder, and the map information can be generated with no problem.

As also described with reference to Fig. 1, the TS2\_VOB is a received digital broadcast recorded directly to disc by the DVD recorder with no intermediate encoding. Because the recorder thus  
5 does not generate the time stamp information and determine the I-picture locations as it does when recording a PS\_VOB, the DVD recorder does not know the internal data structure of the stream and must therefore detect this information from the recorded digital stream.

10 To do this the DVD recorder detects the I-picture and time stamp information for the map information of a TS2\_VOB recording a stream encoded externally to the recorder as follows.

First, I-pictures are detected by detecting the random access presentation information of the TS packet adaptation field  
15 shown in Figs. 12A to 12D. The time stamp information is detected by detecting the PTS in the PES header. Note that the PCR from the adaptation field or the ATS indicating the TS packet arrival time at the DVD recorder can be used instead of the PTS for the time stamp. In any case, the DVD recorder detects I-picture locations based on  
20 information in a high level system layer and does not need to analyze the data structure of the MPEG stream video layer. This is because the system overhead required to analyze the video layer in order to generate the map information is great.

There are also cases in which system layer detection is  
25 not possible. The map information cannot be generated in such cases and it is therefore necessary to indicate that there is no valid map information. The DVD recorder indicates this using the map management information shown in Fig. 15B.

The map management information shown in Fig. 15B  
30 contains map validity information and a self-encoding flag. The

self-encoding flag indicates that an object was encoded by the DVD recorder, and thus indicates that the internal picture structure is known and that the map information time stamp information and I-picture location information is accurate. The map validity  
5 information indicates whether or not there is a valid access map.

Examples of when the system layer cannot be detected include when the adaptation field is not set and when the digital stream is not an MPEG transport stream. Various digital broadcasting standards and formats are used around the world, and there will  
10 naturally be cases in which the DVD recorder records objects for which it cannot generate a map. For example, if a DVD recorder designed for the Japanese market and recording digital broadcasts in Japan is used in the United States to record digital broadcasts in the United States, there will likely be cases in which the DVD  
15 recorder cannot generate a map for the recorded objects.

The DVD recorder can, however, sequentially reproduce from the beginning objects for which map information is not generated. In this case video from the recorded digital stream can be reproduced by outputting it through a digital interface to a STB  
20 appropriate to the stream.

## 6. Basic operation of the playback function

The playback operation of a DVD recorder/player for reproducing content recorded to an optical disc as described above  
25 is described next below with reference to Fig. 18.

As shown in Fig. 18 the DVD player has an optical pickup  
201 for reading data from the optical disc 100, an ECC processor 202 for error correction processing of the read data, a track buffer 203 for temporarily storing the read data after error correction, a PS  
30 decoder 205 for reproducing video objects (PS\_VOB) and other program

streams, a TS decoder 206 for reproducing digital broadcast objects (TS2\_VOB) and other transport streams, an audio decoder 207 for reproducing audio objects (AOB), a still picture decoder 208 for decoding still picture objects (POB), a switching means 210 for  
5 changing data input to the decoders 205 to 208, and a controller 211 for controlling the various parts of the player.

Data recorded to the optical disc 100 is read by the optical pickup 201, passed through the ECC processor 202 and stored to track buffer 203. Data stored to the track buffer 203 is then  
10 input to and decoded and output by the PS decoder 205, TS decoder 206, audio decoder 207, or still picture decoder 208.

The controller 211 determines what data to be read based on the playback sequence defined by the playback path information (PGC) shown in Figs. 16A and 16B. Using the example shown in Figs.  
15 16A and 16B, the controller 211 thus first reproduces part (CELL #1) of VOB #1, then part (CELL #2) of VOB #3, and finally VOB #2 (CELL #3).

Using the cell information of the playback path information (PGC) shown in Fig. 17, the controller 211 also  
20 capture the type of cell reproduced, corresponding objects, and the playback start and end times of the objects. The controller 211 inputs the data for the period of the object specified by the cell information to the appropriate decoder.

The controller 211 also identifies the objects to be reproduced based on the Object ID of the cell information. The  
25 controller 211 also identifies the a cell, which is the playback period of the identified object, by converting the Start\_PTM and End\_PTM of the cell information to a disc address value by referencing the access map of the corresponding VOB information.

30 A player according to this embodiment of the invention

also has a digital interface 204 for supplying the AV stream to an external device. It is therefore possible to supply the AV stream to an external device through an IEEE 1394, IEC 958, or other communications means. This is so that, for example, when the player  
5 does not have an internal decoder for decoding a TS2\_VOB not encoded by the recorder/player the TS2\_VOB can be output directly without decoding through the digital interface 204 to an external STB for decoding and presentation via the STB.

When the digital data is directly output to an external  
10 device, the controller 211 determines whether random access playback is possible based on the map information shown in Fig. 15B. If the access point data flag (random access presentation flag) is valid, the access map contains I-picture location information. In this case the controller 211 is able to access and output digital data  
15 containing an I-picture to an external device through the digital interface in response to fast play and other requests from the external device. Furthermore, time-base access is also possible if the time access information flag is valid. In this case the controller 211 can access and output digital data including the  
20 picture data at a specified playback time to an external device through the digital interface in response to a time-base access request from an external device.

#### 7. Basic operation of the recording function

25 The configuration and operation of a DVD recorder according to the present invention for recording and reproducing an optical disc as described above is described next below with reference to Fig. 19.

As shown in Fig. 19 the DVD recorder has a user  
30 interface 222 for receiving user requests and displaying information

and prompts to the user, a system controller 212 handling the overall management and control of the DVD recorder, an analog broadcast tuner 213 for receiving VHF and UHF broadcasts, an encoder 214 for converting analog signals to digital signals and encoding the digital signals to an MPEG program stream, a digital broadcast tuner 215 for receiving digital satellite broadcasts, an analyzer 216 for interpreting the MPEG transport stream sent from a digital satellite, a display unit 217 such as a television and speakers, and a decoder 218 for decoding the AV stream. The decoder 218 has first and second decoders, for example, such as shown in Fig. 18. The DVD recorder also has a digital interface 219, track buffer 220 for temporarily storing write data, and a drive 221 for writing data to the disc. The digital interface 219 is an IEEE 1394 or other communications interface for outputting data to an external device.

With a DVD recorder thus comprised the user interface 222 first receives a request from the user. The user interface 222 then passes the request to the system controller 212, and the system controller 212 interprets the user request and instructs the various modules to run appropriate processes.

Recording includes self-encoding in which the DVD recorder encodes the input digital data, and outside encoding for recording already encoded digital data to disc without further encoding.

## 7.1 Recording operation by self-encoding

Recording with self-encoding is described specifically first below using by way of example encoding and recording an analog broadcast to a PS\_VOB stream.

The system controller 212 sends a receive command to the analog broadcast tuner 213 and an encode command to the encoder 214.



The encoder 214 then video encodes, audio encodes, and system encodes the AV data from the analog broadcast tuner 213, and passes the encoded data to the track buffer 220.

5 Immediately after encoding starts, the encoder 214 sends the time stamp information at the beginning of the MPEG program stream being encoded to the system controller 212 as the playback start time (PS\_VOB\_V\_S\_PTM), and parallel to the encoding process sends the data required to create the access map to the system controller 212. This value is set as the Start\_PTM of the cell  
10 information shown in Fig. 17 and generated later. The time stamp information is generally the PTS, but the SCR can be used instead.

The system controller 212 then sends a record command to the drive 221, and the drive 221 thus extracts and records data accumulated in the track buffer 220 to the DVD-RAM disc 100. A  
15 contiguous data area (CDA) as described above is also found in the recordable area of the disc and the data is recorded to the located contiguous data area.

Recording typically ends when the user inputs a stop recording command. Stop recording commands from the user are input  
20 through the user interface 222 to the system controller 212, and the system controller 212 then sends a stop command to the analog broadcast tuner 213 and encoder 214.

The encoder 214 stops encoding when it receives the stop encoding command from the system controller 212, and sends the time  
25 stamp information of the last data in the last encoded MPEG program stream to the system controller 212 as the playback end time (PS\_VOB\_V\_E\_PTM). This value is set as the End\_PTM of the cell information shown in Fig. 17. The PTS is normally used for the time stamp information but the SCR can be used instead.

30 After ending the encoding process the system controller

212 generates the presentation control information and VOB information (PS\_VOBI) for the PS\_VOB shown in Figs. 15A and 15B.

5       The VOB information generated here includes map management information and an access map appropriate to the object type. The system controller 212 sets the map validity information of the map management information to "valid," and sets the self-encoding flag ON.

10       Original playback information (O\_PGC information) as shown in Fig. 16A for the recorded object as one of the playback objects is generated as the presentation control information. This O\_PGC information is added to the original playback path table. The original playback path (O\_PGC information) contains cell information. The cell information Type is set to PS\_VOB.

15       The system controller 212 then instructs the drive 221 to stop recording data accumulated in the track buffer 220 and to record the PS\_VOB VOB information (PS\_VOBI) and presentation control information. The drive 221 thus records the remaining data in the track buffer 220 and this information to the optical disc 100, and the recording process ends.

20       It will be obvious that an analog broadcast could be encoded to TS1\_VOB. In this case the encoder 214 must be an encoder for converting the analog signal to a digital signal and encoding the digital signal to the MPEG transport stream, and the cell information Type is set to TS1\_VOB.

25       The PTS or PCR can be used for the Start\_PTM and End\_PTM.

## 7.2 Recording operation by outside encoding

30       Recording with outside encoding is described specifically next below with reference to recording a digital broadcast. The recorded object type in this case is TS2\_VOB.

A digital broadcast recording request from the user is passed from the user interface 222 to the system controller 212. The system controller 212 then instructs the digital broadcast tuner 215 to receive and instructs the analyzer 216 to interpret the received data.

An MPEG transport stream sent from the digital broadcast tuner 215 is passed through the analyzer 216 to the track buffer 220.

To generate the VOB information (TS2\_VOBI) of the encoded MPEG transport stream (TS2\_VOB) received as a digital broadcast, the analyzer 216 first extracts the time stamp information at the beginning of the transport stream as the start time information (TS2\_VOB\_V\_S\_PTM) and sends it to the system controller 212. This start time value is set as the Start\_PTM of the cell information shown in Fig. 17 and generated later. The time stamp information is the PCR or PTS. The ATS indicating the timing at which the object is sent to the DVD recorder could alternatively be used.

The analyzer 216 then analyzes the system layer of the MPEG transport stream to detect the information needed for access map generation. The I-picture locations in the object are detected based on the random access indicator (random\_access\_indicator) in the adaptation field of the TS packet header as described above.

The system controller 212 then outputs a record command to the drive 221, and the drive 221 thus extracts and records data accumulated in the track buffer 220 to the DVD-RAM disc 100. The system controller 212 also instructs the drive 221 where to record on the disc based on the allocation data of the file system. A contiguous data area (CDA) as described above is also found in the recordable area of the disc and the data is recorded to the located contiguous data area.

Recording typically ends when the user inputs a stop recording command. Stop recording commands from the user are input through the user interface 222 to the system controller 212, and the system controller 212 then sends a stop command to the digital broadcast tuner 215 and analyzer 216.

In response to the received stop command from the system controller 212, the analyzer 216 stops interpreting the received data and sends the time stamp information at the end of the last interpreted MPEG transport stream to the system controller 212 as the playback end time (TS2\_VOB\_V\_E\_PTM). This value is set as the End\_PTM of the cell information shown in Fig. 17. The PCR or PTS is used for the time stamp information but the ATS indicating the time when the object was sent to the DVD recorder can be used instead.

After ending the digital broadcast reception process, the system controller 212 generates the presentation control information and VOB information (TS2\_VOBI) for the TS2\_VOB as shown in Figs. 15A and 15B based on the information received from the analyzer 216.

The VOB information generated here includes map management information and an access map appropriate to the object type. The system controller 212 sets the map validity information of the map management information to "valid" if the I-picture locations in the objects were detected and the access map could be generated. The self-encoding flag is set OFF. If a valid access map could not be generated the map validity information is set to an "invalid" state. Examples of when a valid access map cannot be generated include when a corresponding digital broadcast is not received and when there is no random access data set in the adaptation field. If the signal is input directly through the digital interface the signal may also not be an MPEG transport stream, and in this case,

too, the map validity flag is set to "invalid."

Original playback information (O\_PGC information) as shown in Figs. 16A and 16B for the recorded object as one of the playback objects is generated as the presentation control information. This O\_PGC information is added to the original  
5 playback path table. The original playback path (O\_PGC information) contains cell information. The cell information Type is set to TS2\_VOB.

The system controller 212 then instructs the drive 221  
10 to stop recording data accumulated in the track buffer 220 and to record the TS2\_VOB VOB information (TS2\_VOBI) and presentation control information. The drive 221 thus records the remaining data in the track buffer 220 and this information to the optical disc 100, and the recording process ends.

While the above recording operations are described with  
15 reference to user-input recording start and end commands, it will be obvious that the same essential operation applies to timer recordings controlled by a VCR, for example. In this case the system controller automatically issues the recording start and end commands  
20 instead of the user, and there is no essential change in DVD recorder operation.

#### 8. Outline of the invention

A data recording medium according to the present  
25 invention is a medium for recording data of various different formats, including analog broadcast or digital broadcast content and various types of data input through an analog/digital interface. A data recording apparatus according to the present invention is an apparatus for recording AV data to and reproducing AV data from the  
30 same data recording medium.

More particularly, externally input AV data is recorded as an MPEG\_TS, and a stream adding decoder input time data for each MPEG\_TS packet to each MPEG\_TS packet is recorded to the data recording medium of the present invention.

5           Recorder specific or content specific information and the locations of PSI (Program Specific Information) packets containing MPEG\_TS control information are also embedded as a user private stream (UP packet), and the decoder input time of each packet is added in a format suitable for accumulation.

10           Furthermore, so simplify conversion to an MPEG\_PS when multiplexing the MPEG\_TS, data less than one pack (2048 bytes) is system encoded as one continuous multiplexing unit, and an MPEG\_TS is recorded while allocating each continuous multiplexing unit to one or plural MPEG\_TS packets.

15

## 9. Detailed embodiments of the invention

### First Embodiment

The basic recording and playback operations of a data recording and reproducing apparatus according to the present  
20 invention are substantially as described above, and only the basic operation for recording analog line input is therefore described specifically below with reference to Fig. 20. The recorded object type in this case is TS1\_VOB.

25           Analog line input recording requests from a user are passed from the user interface 222 to the system controller 212. The system controller 212 then sends a receive command to the line input unit 223 and a data encoding command to the encoder 214.

The MPEG transport stream from the encoder 214 is sent to the track buffer 220.

30           To generate the VOB information (TS1\_VOBI) of the

encoded MPEG transport stream (TS1\_VOB), the encoder 214 first sets the time stamp information as the presentation start time (TS1\_VOB\_V\_S\_PTM) and sends it to the system controller 212. This start time value is set as the Start\_PTM of the cell information generated later and shown in Fig. 17. The time stamp information is the PCR or PTS.

The encoder 214 also generates the data needed for access map generation while generating the MPEG transport stream. This is done by, for example, storing the adaptation field in the first MPEG transport packet of the I-picture, setting the random\_access\_indicator bit, and notifying the system controller 212 of the start of a VOBU.

The system controller 212 then sends a record command to the drive 221, and the drive 221 extracts and records data from the track buffer 220 to the DVD-RAM disc 100. The system controller 212 also instructs the drive 221 where to record on the disc based on the allocation data of the file system. A contiguous data area (CDA) as described above is also found in the recordable area of the disc and the data is recorded to the located contiguous data area.

Recording typically ends when the user inputs a stop recording command. Stop recording commands from the user are input through the user interface 222 to the system controller 212, and the system controller 212 then sends a stop command to the encoder 214.

In response to the received stop command from the system controller 212, the encoder 214 stops the encoding process and sends the time stamp information included in data at the end of the last encoded MPEG transport stream to the system controller 212 as the end presentation time (TS1\_VOB\_V\_E\_PTM). This value is set as the End\_PTM of the cell information shown in Fig. 17. The time stamp information becomes PCR or PTS.

After ending the recording process, the system controller 212 generates the playback control information and VOB information (TS1\_VOBI) for the TS1\_VOB as shown in Figs. 15A and 15B based on the information received from the encoder 214.

5           The VOB information generated here includes an access map and map management information those adapted to the object type. The system controller 212 sets the map validity information of the map management information to "valid". The self-encoding flag is set ON.

10           Original playback path information (O\_PGC information) as shown in Figs. 16A and 16B for the recorded object as one of the playback objects is generated as the presentation control information. This O\_PGC information is added to the original playback path table. The original playback path information (O\_PGC  
15           information) contains cell information. Type information of the cell information is set to "TS1\_VOB".

The system controller 212 then instructs the drive 221 to stop recording data accumulated in the track buffer 220 and to record the VOB information (TS1\_VOBI) and playback control  
20           information for TS1\_VOB. The drive 221 thus records the remaining data in the track buffer 220 and this information to the optical disc 100, and the recording process ends.

The self-encoding MPEG transport stream generated by the encoder 214 is described in further detail below.

25           The structure of the self-encoding MPEG transport stream is shown in Figs. 21A and 21B. As shown in the figure the self-encoding MPEG transport stream is segmented into VOBU units. Each VOBU starts with a PAT packet, PMT packet, and a User Private packet (UP packet) embedded with stream-specific data. A PAT packet and PMT  
30           packet at least are also located at the beginning of the VOB.



As shown in Fig. 21B an ATS indicating the decoder input time is also added to each packet, and each packet is input to the decoder at the time intended by the ATS.

5 The self-encoding program information (such as the PMT packet PID) is stored to the PAT packet of the first packet and input to the decoder at the time indicated by ATS1.

The PID for each elementary stream composing the program is stored to the PMT packet of the second packet. In this example PIDs for the video, audio, data broadcast ("Data" in the figure),  
10 and user private ("private" in the figure) packets are stored.

Information added to the stream is stored to the user private packet in the third packet. This added information could, for example, include: stream title information; recording date and time information; stream attributes, that is, stream encoding  
15 information such as the bit rate, video resolution, frame rate, aspect ratio, or encoding method; input source identification information for identifying whether the line input is analog or digital; information indicating the AV data encoding method if the data is digital; copyright protection information indicating whether  
20 copying is allowed or prohibited; Vertical Blanking Interval (VBI) signals such as closed caption (CC) data, teletext data, or Wide\_Screen Signaling (WSS) data used for display control; information indicating system encoding conditions; DVD standard compatibility information; menu information provided for user  
25 convenience using specific data provided by the manufacturer that recorded the stream; and data useful for conversion to various DVD standard MPEG program streams (MPEG\_PS).

The decoder input time for a packet stored in this added information and located in the MPEG transport stream as above is  
30 described next with reference to Figs. 22A and 22B.

Fig. 22A is a block diagram showing the basic configuration of a decoder referred to as a transport stream system target decoder (T\_STD). This figure further shows a system decoder 235 for interpreting a PSI packet and providing decoder control (not described above).

When a PAT (PSI packet), or PMT packet, as PSI packet, is input to the T\_STD, the packet is discriminated according to packet type by demultiplexer 232, and the PSI packet which is used for system control is sent immediately to a transport buffer 233.

10 Data accumulated in the transport buffer 233 is then streamed to the system buffer 234 at a rate of 1,000,000 bits/second (=Rsys).

The PSI data becomes valid the moment the required PSI data is accumulated in the system buffer 234.

15 This T\_STD model in MPEG thus defines an operating model for the decoder and defines standards for the MPEG transport stream transfer rate, for example.

There are several restrictions on PSI packet transfer because the data recording apparatus must self-encode the transport stream according to an MPEG transport stream format that assures the T\_STD can correctly decode the transport stream. A method of determining the ATS that determines the packet transfer rate is described next with reference to Fig. 22B.

25 When reproducing a self-encoding stream the leading PAT, PMT, and UP packets are input to the T\_STD at the time indicated by ATS1, ATS2, and ATS3, respectively.

The PMT packet and UP packet are now considered, in order to interpret, by the T\_STD, the PID of the UP packet specified by the PMT packet and valid it, the last byte (byte m) of the TS\_program\_map\_section must be stored in the system buffer 234.

That is, for the PMT to be valid  $(m+n+5) \times 8 / R_{sys}$  seconds must have passed from ATS2 as the PMT packet input time. Note that  $n$  is the byte length of the PMT packet adaptation\_field.

Because the System Clock Frequency (SCF) as the T\_STD reference clock is 27,000,000 Hz (with a defined tolerance range of  $\pm 810$  Hz for error), the following relationship between ATS3 and ATS2 must be true if the ATS is a time expressed to the precision of the System Clock Frequency.

$$ATS3 \geq ATS2 + ((m+n+5) * 8 / R_{sys}) * SCF$$

Because the shortest interval between ATS2 and ATS3 is only when there is no adaptation\_field ( $n = 0$ ) in the PMT packet and the smallest TS\_program\_map\_section (21 bytes) is stored in the PMT packet, a time interval of  $208 / R_{sys} \times SCF$  is shortest.

The following relationship is likewise required for the input time ATS1 of the PAT packet and input time ATS2 of the PMT packet

$$ATS2 \geq ATS1 + ((m_0+n_0+5) * 8 / R_{sys}) * SCF$$

where  $m_0$  is the byte length of the Program association section in the PAT packet, and  $n_0$  is the byte length of the adaptation\_field in the PAT packet.

Furthermore, because the shortest interval between ATS1 and ATS2 is only when there is no adaptation\_field ( $n = 0$ ) in the PAT packet and the smallest Program association section (16 bytes) is stored to the PAT packet, a time interval of  $168 / R_{sys} \times SCF$  is shortest.

If time is expressed with a precision of 27 MHz using a System Clock Frequency (SCF) of 27 MHz, the shortest time interval between ATS1 and ATS2 and between ATS2 and ATS3 is 4536 and 5616, respectively.

Storing the User Private packet to the self-encoding

transport stream is described next with reference to Figs. 23 to 26.

Fig. 23 shows storing the UP packet when the UP packet is defined as a User Private stream. In this case an identification number greater than or equal to "0x80" and less than or equal to "0xFF" is allocated to stream\_type of the PMT corresponding to the UP packet. A unique PID is assigned to the UP packet. The internal data structure of the UP packet does not conform to the MPEG standard. Note that in this example the UP packet includes a section structure called the DVD\_attribute\_section().

Fig. 24 shows a further storage method whereby a private\_section structure is included in the UP packet and a unique PID is assigned. The data structure of the private\_section will vary somewhat according to the value of the section\_syntax\_indicator in the private\_section, but data specific to the UP packet is stored in the private\_data\_byte of the private\_section. In this case, identification number of 0x00 is assigned to stream\_type.

Fig. 25 shows a method of storing a UP packet as a packet with the same PID as the PMT packet. In this case the UP packet data structure conforms to the private\_section structure. The stream type is not defined, and PID of PMT packet is assigned to UP packet.

Fig. 26 shows an example in which the UP packet is not stored separately but is enclosed in the PMT packet. In this case the specific data equivalent to the UP packet has a private\_section structure, and the private\_section is written after the TS\_program\_map\_section. That is, PMT packet includes both TS\_program\_map\_section and private\_section.

The specific data stored to the MPEG\_TS by the above-noted methods is described next.

As shown in Figs. 23 to 26, this specific data includes

the Real-time Data Information General Information (RDI\_GI) of the RDI Unit and the Display Control Information and Copy Control Information (DCI\_CCI) of the DVD Video Recording standard.

5       The RDI\_GI stores the first presentation start time (VOBU\_S\_PMT) of the VOB and the recording date and time information. The DCI\_CCI stores, for example, the VOB aspect ratio information, subtitle mode information, film or camera mode information and other information related to display control, copy generation management information, APS information, and input source information. (For  
10       further information about RDI\_GI and DCI\_CCI, see the DVD Video Recording standard.)

      The V\_ATR field stores the video bit rate, resolution, frame rate (or video\_format such as NTSC or PAL), aspect ratio, and encoding method (an MPEG2\_Video or MPEG1\_Video identifier).

15       Likewise, the A\_ATR field stores the bit rate for all or part of the audio, encoding method, channel count, quantization bits, and dynamic range control information according to the number of audio streams.

      The CC field stores the closed caption data for the VOB.  
20       To improve the transferability of PS conversion, closed caption data can be written in an extension\_and\_user\_data (1) format (a method of storing user data to the GOP layer), or the closed caption data could be written separately.

      Storing the closed caption data to the user data of the  
25       GOP layer improves MPEG\_PS conversion efficiency because the DVD Video and DVD Video Recording standards are defined for this purpose.

      The C\_SE field stores information relating to some problems associated with TS2PS conversion of the VOB or VOB.

      Regarding the CC, WSS, or teletext data storage location  
30       information, that information indicates whether, for example, closed

caption data is contained in the UP packet, whether closed caption data is written as user data to the picture headers, or whether there is no closed caption data in the particular VOB (or VOB).

5       Regarding the WSS storage location information, that information further indicates whether it is stored as specific data in the UP packet, or whether it is written to the user data in the picture headers.

10       Regarding the teletext storage location information, it indicates whether a TS packet is provided for storing the teletext data, or whether it is written to the user data in the picture headers.

15       Regarding the multiplexed block structure and transfer information, that information includes information indicating if the number of TS packets in the multiplex block (a data block in which only one elementary stream is stored without being mixed with another elementary stream) as shown in Figs 27A to 27H is fixed or variable, the number of packets if the number is fixed, information indicating whether a PTS/DTS is added to the first TS packet in the multiplex block, or the transfer rate within the same multiplex block. During MPEG\_TS encoding imposing no conditions on  
20       conventional multiplexing, the multiplex block can be written with a fixed length including only one TS packet.

25       The decoder buffer control information includes vbv\_delay, a parameter of the video verifying buffer, information such as vbv\_buffer\_size indicating the remaining video buffer capacity (this information is used to determine how far ahead of the ATS input time the video data can be read), and the time difference between the decoding time and the input completion time of the VOB frame for which the buffer input time is closest to the frame  
30       decoding time (this information is used to determine how far back

from the ATS input time the video or audio data can be read).

The DVD\_Compatibility information indicates the overhead involved with system transcoding a MPEG\_TS to a MPEG\_PS conforming to a DVD standard.

5. The DVD\_Compatibility information indicates how easy it is to convert a MPEG\_TS to other DVD formats. For example, if the multiplex blocks are 2 KB or less, a level 1 indicator is set; if there is closed caption, WSS, or teletext data, the closed caption or WSS data is stored to an UP packet, and the teletext data is stored as a teletext packet in a multiplex block storing video data, a level 2 indicator is set; if it is not necessary to consider buffer management when the closed caption, WSS, or teletext data is stored to the area specified by the DVD standard, a level 3 indicator is set; and if it is not necessary to consider buffer management when the ATS of the first TS packet in the multiplex block is replaced by the SCR, a level 4 indicator is set.

This DVD\_Compatibility information is thus a data set indicating the ease of convertibility to various DVD formats, including DVD Video, DVD Audio, DVD Video Recording, and DVD Stream Recording.

Figs. 27A to 27H show the structure of an MPEG\_TS using multiplex blocks, and the data structure when this MPEG\_TS is converted to DVD Video and DVD Video Recording formats.

The self-encoded TS stream shown in Fig. 27A comprises the VOBUs (playback and decoding units) of the self-encoded TS stream shown in Fig. 27B. As shown in Fig. 27C one VOBUs includes multiple multiplex blocks (corresponding to MPEG\_PS packs). Each multiplex block can be segmented into fixed length data units as shown in Fig. 27D (enabling easy packaging in the device) or into variable length data units as shown in Fig. 27E (thereby consuming less disc space).

In the cases shown in Figs. 27D and 27E the multiplex blocks are respectively formed by segmenting non-elementary streams such as PSI/SI packets or UP packets and the elementary stream, but as shown in Fig. 27F a multiplex block could store both an elementary stream and non-elementary stream objects such as PSI/SI packets or UP packets. Note that in Fig. 27F multiplex block #1 and multiplex block #2 are one multiplex block.

The above streams can be easily converted to the DVD Video format shown in Fig. 27G or the DVD Video Recording format shown in Fig. 27H.

In this case it is important for simple TS2PS conversion that the MPEG\_PS packs are formed in the multiplex block sequence and one multiplex block is the unit storing one pack of data.

It should be noted that the capsule header and ATS are only loosely related to the present invention and are therefore omitted in Figs. 27A to 27H. In addition, the packs in the converted MPEG\_PS shown in Figs. 27G and 27H are also stuffed or padded as appropriate according to the byte length and VOB alignment of the stored elementary.

Figs. 28A to 28G describes the multiplexing method of the present invention, comparing with the conventional stream multiplexing method shown in Fig. 8. As shown in the figure the final format conforms to the MPEG\_TS format shown in Fig. 28G. The video stream (Fig. 28A) comprises plural GOP (Fig. 28B). Each GOP contains specific picture data, and a TS packet group of a data size equivalent to the data size of one pack when converted to an MPEG\_PS is one multiplex block (Fig. 28C). That is, one multiplex block is segmented into plural TS packets equivalent to the data size of one pack as shown in Fig. 28D. The audio stream is likewise packed in one multiplex block group having a plurality of TS packets. As shown



in Fig. 28E, a VOB is formed by multiplexing by multiplex block unit. The greatest difference between the present invention and the prior art shown in Fig. 8 is in that data units of a size equivalent to the data size of one MPEG\_PS pack are grouped to form the multiplex blocks (see Fig. 28E).

Furthermore, the ATS may be added to each MPEG\_TS packet while increased by a specific amount ( $\Delta\text{ATS}$ ) in each packet within the same multiplex block as shown in Fig. 29. This is effective to avoid complex buffer management during TS2PS conversion, and convert ATS to SCR using a simple offset or no offset.  $\text{ATS}_i$  ( $i = 0, 1, 2, \dots$ ) in this case satisfies the following equation.

$$\text{ATS}_i + (\text{packet count in the multiplex block}) \times \Delta\text{ATS} \leq \text{ATS}_{i+1}$$

When the multiplex block is a fixed length, the number of TS packets in one multiplex block is fixed and thus the multiplex block boundaries are easily known. However, when the multiplex block is variable length, the number of TS packets in one multiplex block is also variable and thus the multiplex block boundaries are not easily known. Therefore, the increase ( $\Delta\text{ATS}$ ) in the ATS at the multiplex block boundary is set to a specific value different from the (constant) increase within the multiplex block. That is, the difference ( $\Delta\text{ATS}$ ) between the ATS of the last packet in the previous multiplex block and the ATS of the first packet in the immediately following multiplex block is set to a specific value which is not the constant value. This makes it possible to know the multiplex block boundaries by monitoring  $\Delta\text{ATS}$ . A 1:1 correlation between packs and TS packets when converting to an MPEG\_PS can therefore be assured.  $\text{ATS}_i$  in this case satisfies the following equation.

$$\text{ATS}_i + (\text{packet count in the multiplex block}) \times \Delta\text{ATS} < \text{ATS}_{i+1}$$

Furthermore, the  $\text{ATS}_i$  added to the first packet in the MPEG\_TS multiplex block corresponds to  $\text{SCR}_i$  added to each pack in

the MPEG\_PS after conversion.

Furthermore, as also shown in Fig. 29, closed caption, DSI, or other text information can also be stored in the UP packet. The DSI in the UP packet is used to generate NV\_PCK data after conversion, and the closed caption data is stored to the video pack. To enable compatibility with the PAL standard used in Europe, packets storing teletext data in the multiplex block can be inserted between the video data packets as shown in Fig. 30. In this case the teletext data packets are located immediately before the simultaneously presented picture having the same PTS. After conversion the teletext data is stored to the video pack.

Fig. 31 shows the data structure of a UP packet storing the DSI as described above.

Information (such as a relative number from the beginning of the VOB) identifying the TS packet storing the last byte of the first I-picture in the VOB can also be described in the added information of the UP packet to enable efficient special playback modes. Special playback modes can also be supported by also describing picture encoding type information of some of I- and P-pictures or all pictures in the VOB, the data size of each picture (such as information identifying the TS packet containing the last byte), and information indicative of the DTS/PTS for each picture.

It should be noted that if encoding is done so that TS packet containing the PTS/DTS is located at the beginning of the multiplex block in the present embodiment, the beginning of an access unit will be located at the beginning of the packs after TS2PS conversion, and simplified DVD-specific header processing can be expected.

To prevent an overflow of data stored to MPEG\_PS packs and ease conversion to an MPEG\_PS, the TS packets of the multiplex

blocks can be appropriately stuffed or a necessary number of stuffing bytes can be inserted after the last TS packet in the multiplex block.

5       The present embodiment has been described primarily with reference to recording to DVD, but the invention will obviously not be so limited. More specifically, after recording a self-encoded transport stream to a hard disk, semiconductor memory, or other data recording medium, a stream converted to an MPEG program stream can be recorded to the same medium or to a different medium.

10       Furthermore, the PAT, PMT, and UP packets are described as recorded to the beginning of each VOB in the present embodiment, but they can be recorded to the beginning of at least a VOB or to the beginning of a Cell which is the playback management unit.

15       Yet further, this embodiment is described recording PAT, PMT, and UP packets, but the UP packet can be omitted.

      Yet further, the PAT, PMT, and UP packets are described as fixed at the beginning in the present embodiment, but the invention shall not be so limited, and a packet storing a Null packet can be recorded inserted therebetween.

20       Yet further, a self-encoded stream is described starting from a PAT packet, but the invention shall not be so limited and the stream could start from a Null packet.

25       Furthermore, the system transfer rate can be set to a fixed rate by appropriately inserting Null packets in the self-encoded stream.

      It should also be noted that a data area for storing manufacturer-private information can be provided as shown in Fig. 7, and MPEG\_TS system encoding conditions can be written to this data area.

30       It should also be noted that all or part of the

information written to the UP packet in the above embodiment can be written to the TS1\_VOB information shown in Fig. 15.

It will also be noted that the DVD Video format does not allow for dual mono audio. It is, however, possible to convert a self-encoding transport stream recorded with dual mono audio channels to the DVD Video format by separating the dual mono audio channels into two separate audio streams recorded as left and right monaural audio channels.

Part or all of the parameters written to the UP packet in the above embodiment could also be written into the management information. By thus avoiding recording a parameter that does not change within a self-encoding transport stream multiple times, recording space is not wasted and the decoder does not need to waste processing time trying to determine whether or not the parameter changed each time a UP packet is detected.

#### Second Embodiment

##### < Encoder configuration >

An alternative embodiment of the present invention is described next below. The description is made to an encoder of a data recording apparatus according to the present invention by focusing first the encoding process to receive and self-encode AV input to an MPEG transport stream.

Fig. 33 shows the configuration of the encoder in a data recording apparatus according to the present invention. As shown in the figure the encoder 214 includes elementary stream encoders 230a, 230b and 230c, and a system encoder 232. The encoder 214 receives a control signal from the system controller 212 and then runs the encoding process with the elementary stream encoders 230a, 230b and 230c, or the system encoder 232 while switching between elementary

encoding and system encoding. Each of the elementary stream encoders 230a, 230b and 230c receives video, audio, and VBI (Vertical Blanking Interval) signals for encoding.

5 The video encoder 230a receives a control signal from the system controller 212 and based thereon encodes the bit rate, resolution, aspect ratio, and other attributes of the video stream within a predefined range. More specifically, the video encoder 230a receives a control signal from the system controller 212 specifying the operating mode as the "DVD Video compatible mode," DVD Video  
10 Recording compatible mode," or "normal mode." If the mode specified by the control signal is the DVD Video compatible mode, the video encoder 230a generates a video stream conforming to the video attributes of the DVD Video standard; if the DVD Video Recording compatibility mode, it generates a video stream conforming to the  
15 video attributes of the DVD Video Recording ("DVD VR" below) standard; and if the normal mode, generates a video stream conforming to a specific attribute range.

The audio encoder 230b likewise receives a control signal from the system controller 212 and based thereon encodes the  
20 bit rate, quantization rate, channel count, and other attributes of the audio stream within a predefined range. Like the video encoder 230a, the audio encoder 230b specifically receives a control signal from the system controller 212 specifying the operating mode. If the mode specified by the control signal is the DVD Video compatibility  
25 mode, the audio encoder 230b generates an audio stream conforming to the audio attributes of the DVD Video standard; if the DVD VR compatibility mode, it generates an audio stream conforming to the audio attributes of the DVD Video Recording ("DVD VR" below) standard; and if the normal mode, generates an audio stream  
30 conforming to a specific attribute range.

The VBI data encoder 230c likewise receives a control signal specifying the operating mode from the system controller 212 and encodes the VBI data accordingly. Specifically, if the elementary stream encoding control signal input from the system controller 212 to the VBI data encoder 230c indicates the DVD Video compatible mode or DVD VR compatible mode, it additionally encodes VBI data according to the VBI data storage method specified by the respective standards. There is a case that a VBI data storage method is separately defined even in the original normal mode, and in that case "additionally encode" means that VBI data is redundantly stored to the elementary stream.

The encoded elementary streams are then multiplexed to the MPEG\_TS system stream by the system encoder 232.

Like the elementary stream encoders 230a, 230b and 230c, the system encoder 232 also receives an encoding control signal from the system controller 212 to encode according to the received signal.

The control signal from the system controller 212 to the system stream encoder 232 is either a system encoding control signal for encoding a normal MPEG\_TS, or a system encoding control signal (DVD-Video mode or DVD-Video Recording mode) applying constraints on the normal MPEG\_TS in order to enable easy conversion to an MPEG\_PS (particularly a specific DVD format).

If the control signal is for encoding a normal MPEG\_TS, the system stream encoder 232 applies the system encoding to the elementary streams input from the elementary stream encoders 230a, 230b and 230c while managing the buffers so that the input streams are not corrupted by the decoder model (T\_STD) which is a reference for the MPEG\_TS system stream.

If the control signal from the system controller 212 is a control signal specifying system encoding to an MPEG\_TS enabling

easy conversion to an MPEG\_PS, the encoding is conducted while also following additional special system encoding rules.

The encoder 214 then outputs the resulting self-encoding MPEG\_TS system stream.

5           The data recording apparatus according to the present invention is thus characterized by switching the encoding mode at the elementary stream and system stream encoding levels. The processes applied in each encoding mode to convert to a particular DVD format when the encoding mode is changed as described above are  
10 shown in the table in Fig. 34.

          An MPEG\_TS enabling easy conversion to an MPEG\_PS is thus generated by driving the elementary stream encoders 230a, 230b and 230c and system encoder 232 to encode the respective streams assuming the conversion to an MPEG\_PS.

15           < A self-encoded MPEG\_TS >

          A detailed embodiment of the format of an MPEG\_TS self-encoded by a data recording apparatus according to the present invention is described next below. The differences between a normal  
20 MPEG\_TS ("SESF" below) and an MPEG\_TS enabling easy conversion to an MPEG\_PS (a "Constrained SESF" below) are also described.

          In the following example, information presenting the stream encoding conditions is stored to the VOB1 storing attributes and other information in MPEG\_TS stream units. By thus storing  
25 information about the encoding conditions to the management information and not in the stream, it is possible to quickly determine whether a stream can be easily converted to a DVD Video or DVD VR format without analyzing the stream. Note that this information presenting the stream encoding conditions can be stored  
30 to a Tip packet which is described further below.

The information presenting the stream encoding conditions is represented by an "encode\_condition" flag which has two bits. The flag value is described below.

00b: normal MPEG\_TS (SESF)

5        01b: MPEG\_TS enabling easy conversion to a DVD VR stream format (Constrained SESF)

10b: reserved

11b: MPEG\_TS enabling easy conversion to a DVD Video stream format (Constrained SESF)

10        Two cases are possible if the encode\_condition flag is set to 00b in the stream management information: the stream is originally encoded without considering high speed conversion to MPEG\_PS, and a sequence of MPEG program streams are linked by user editing for easy conversion to individual MPEG program streams.

15        If the encode\_condition flag is also set in the stream, it is meaningless to set encode\_condition = 00b indicating a normal MPEG\_TS in the stream. It is therefore also possible for the encode\_condition flag to be used differently inside and outside the stream, reserving the encode\_condition = 00b setting so that it is  
20 not used in the stream (in the Tip packet described below).

By thus setting this flag, it is possible to determine from the value of the VOB\_I encode\_condition field whether the stream can be easily converted to a DVD Video or DVD VR format. "Easily converted" as used herein means convertible by the conversion method  
25 described further below.

< Constrained SESF stream structure >

Fig. 80 shows the complete stream structure of a Constrained SESF. A Constrained SESF includes plural SESF capsules.  
30 An SESF capsule contains specific multiplexing units, and a Tip



packet (detailed below) at the head. The presentation time stamp (PTS) of each SESF capsule and an address of the Tip packet are correlated in the access map 80c. As described below, for TS2PS conversion, a conversion process is accomplished in SESF capsule units.

Fig. 32 shows the correlation between MPEG\_PS packs and packets in on SESF capsule. As shown in Fig. 32 a TS packet (Tip packet below) storing stream-specific information is inserted to a Constrained SESF. The Tip packet embedded in a Constrained SESF is described below with reference to Fig. 35 to Fig. 41.

< Tip packet >

Fig. 35 shows the overall Tip packet structure. As shown in Fig. 35, a Tip packet stores a Data\_ID identifying the packet as a Tip packet, display\_and\_copy\_info corresponding to the DVD VR DCI\_CCI field and including display control and copy control information, encode\_info storing stream encoding information, and MakersPrivateData for storing additional information unique to the manufacturer.

As shown in Fig. 35 and Fig. 36, the PCR value needed for the SCR calculations described below is written to the adaptation field of the Tip packet. This adaptation field is a fixed byte length, and thereby enables accessing information in the Tip packet using a fixed address.

The Data\_ID structure is shown in Fig. 37. The Data\_ID has a Data\_Identifier for identifying whether the corresponding packet is a Tip packet. The Data\_Identifier is a 3-byte field holding a value of "0x544950" expressing "TIP" in the ASCII code. The decoder of the playback device reads the value of this field to identify that it is a Tip packet.

The display\_and\_copy\_info structure is shown in Fig. 38. Generating the RDI pack when converting a Constrained SESF to the DVD VR format is simplified by providing the same structure and information as the DCI\_CCI field of the RDI Unit in the DVD VR standard in display\_and\_copy\_info. (Note that the DCI\_CCI field of the DVD VR standard is fully described in "DVD Specifications for Rewritable/Re-recordable Disc, Part 3, VIDEO RECORDING," and in Japanese patent No. 3162044. While some of the field names are different in these documents, the field definitions are the same so as to enable direct copying when converting to the DVD VR format.)

The encode\_info\_field structure is shown in Fig. 39. Resolution information for the video stream following the Tip packet is written to the video\_resolution field. The value of encode\_info is shown below.

0000b: 720 x 480 (NTSC), 720 x 576 (PAL)  
0001b: 704 x 480 (NTSC), 704 x 576 (PAL)  
0010b: 352 x 480 (NTSC), 352 x 576 (PAL)  
0011b: 352 x 240 (NTSC), 352 x 288 (PAL)  
0100b: 544 x 480 (NTSC), 544 x 576 (PAL)  
0101b: 480 x 480 (NTSC), 480 x 576 (PAL)

Others: reserved

Resolution can vary during a single continuous recording in the DVD VR format. However, streams of different resolutions are managed as separate VOBs and it assures seamless connection during playback by a certain recorder. This field is therefore used to determine where it is necessary to split the VOB when converting to the DVD VR format, if there is a resolution change during Constrained SESF recording.

In a Constrained SESF recorded with consideration for converting to the DVD Video format (encode\_condition = 11b), the

resolution does not change within a single stream.

5       The encode\_condition field is the same as the value stored to the VOB\_I (except when 00b). The reason why the encode\_condition field is stored and embedded in the stream and not only in the stream management information is to enable the recorder to easily determine if it is possible to convert to the DVD format by referencing the encode\_condition field in the Tip packet when, for example, a stream is copied through a digital interface such as IEEE 1394.

10       VOBU\_S\_PTM of the DVD VR standard is recorded to the FVFPST field. This is to eliminate the process of analyzing the video stream encoded after the Tip packet and calculating the presentation time of the first appearing video field when converting a Constrained SESF to a DVD Video or VR format.

15       The FVFPST field includes a 32-bit field denoting the video field presentation time at 90 KHz precision, and a 16-bit field denoted at 27 MHz precision.

20       The PES\_info structure is shown in Fig. 40. PES\_info is needed to convert a Constrained SESF to the DVD Video format without analyzing the elementary streams. This information is needed to generate the information inserted to the DVD Video stream and stored in the packs, referred to as NV\_PCK, supporting special playback modes.

25       The PES\_info can store information for 136 PES packets each storing video data or audio data units. Four bits are assigned to each PES packet, and the NV\_PCK information can be generated without analyzing PES packet content. PES packets not storing video or audio data are ignored.

30       In a SESF capsule being the data unit from one Tip packet to the packet immediately preceding the next Tip packet, a

PES\_existence\_flag declares if the j-th PES packet is present in the SESF capsule. The value of PES\_existence\_flag is set as follows.

0b: j-th PES packet is not in the SESF capsule

1b: j-th PES packet is in the SESF capsule

5           If the PES\_extension\_flag = 0b (when there is no PES packet), all remaining fields in the PES packet are set to 0b.

The PES\_payload\_identifier identifies whether the data stored in the PES packet is video or audio data. PES\_payload\_identifier values are set as follows.

10           0b: video stream

1b: audio stream

The PES\_existence\_flag and PES\_payload\_identifier fields are set for all relevant PES packets.

15           When it is determined from the PES\_payload\_identifier whether video or audio data is stored, the remaining field definitions vary according to the type of stream stored in the PES packet.

            If the PES packet stores a video stream (PES\_payload\_identifier = 0b), picture\_coding\_type indicating the type of picture stored in the PES packet is defined after the PES\_payload\_identifier field.

The value of the picture\_coding\_type field is set as follows.

00b: a picture encoded with encoding other than 01b or 10b

25           01b: a frame encoded I-picture; a pair of field encoded I-pictures; or a pair of field encoded I-picture and field encoded P-picture

10b: a pair of frame encoded P-pictures or a pair of field encoded P-pictures

30           11b: reserved

In other words, a picture with 01b or 10b is a picture used as the reference picture defined by the DVD Video standard. The above description is for information added to PES packets storing video.

5                If the PES packet stores an audio stream (PES\_payload\_identifier = 1b), the PES\_payload\_identifier is followed by a stream\_identifier and a sync\_presentation\_flag. The stream\_identifier identifies whether the audio stream in the PES packet is a first audio stream or a second audio stream. The  
10                sync\_presentation\_flag is a flag to identify whether there is an audio frame for which presentation begins simultaneously to or immediately following the FVFPST field (the presentation start time of the video field presented first) written to each Tip packet.

                 The value of stream\_identifier is set as follows.

15                0b: first audio stream

                 1b: second audio stream

                 The first and second audio stream can be discriminated by the PID setting rules and the order of elementary stream declaration in the PMT.

20                The value of sync\_presentation\_flag is set as follows.

                 0b: an audio frame for which presentation begins simultaneously to or immediately following the FVFPST is not stored in the audio PES packet

                 1b: an audio frame for which presentation begins  
25                simultaneously to or immediately following the FVFPST is stored in the audio PES packet

                 Information added to PES packets storing audio is as described above.

                 The PES\_info field thus extracts and stores information  
30                for each PES packet following a Tip packet.

Fig. 41 shows the MakersPrivateData. As shown in the figure, the MakersPrivateData has a maker\_ID field identifying the manufacturer of the Constrained SESF, and maker\_private\_data field containing specific additional information described by the manufacturer.

Figs. 42A and 42B shows an example of a value of PID of the Tip packet and a value of stream\_type indicating the stream type. Other PID and stream\_type values are reserved by the MPEG standard and other standards, and these values were selected to indicate private data beyond the scope of the MPEG standard without interfering with reserved values.

Various stream attribute information is thus extracted and stored to the Tip packets stored in a Constrained SESF. How the fields described above are used during conversion to a different DVD format is described in further detail below.

#### < System encoding conditions >

The system encoding conditions for a Constrained SESF are described in detail next below. Note that the following system encoding conditions do not apply to a normal SESF.

#### < Multiplexing Unit >

TS packet storing elementary streams in a Constrained SESF is composed of a Multiplexing Unit which is a unit of data stored in 2 KB packs according to a DVD format. Note that this Multiplexing Unit corresponds to the multiplex block of the first embodiment.

Only TS packets storing one type of elementary stream are stored to each Multiplexing Unit, and these TS packets are not mixed with TS packets storing another type of elementary stream.

Mixing TS packets with Null packets is not prohibited because it may be necessary to include one or more Null packets in order to generate a Multiplexing Unit (such as the Multiplexing Unit storing the last part of a stream). This is necessary to clarify the relationship between Multiplexing Units and packs.

One Multiplexing Unit contains eleven continuous TS packets, and the elementary stream (payload data) in each Multiplexing Unit is stored completely within the one corresponding pack. This likewise constrains the relationship to the pack.

When the PES packet storing the video stream is segmented and placed in multiple Multiplexing Units, all Multiplexing Units other than the Multiplexing Unit containing the last byte of the PES packet store a TS packet payload data of  $184 \times 11 = 2024$  bytes. This allows stream transfers to be completed most efficiently and successive processing by TS packet unit to be easily accomplished during TS2PS conversion. If the size of Multiplexing Units other than the last Multiplexing Unit is less than 2024 bytes, it will not be possible to easily determine the value of the PES\_packet\_length field stored to the packet header of each pack in the MPEG\_PS when converting the first TS packet of the Multiplexing Unit during TS2PS conversion.

The first complete audio frame data in the Multiplexing Unit should be an audio frame placed at the beginning in the payload of PES packet. This is easy to understand by considering

storing PES packets storing the audio stream to multiple Multiplexing Units. If one audio PES packet is segmented and placed in multiple Multiplexing Units, it is necessary to identify the PTS and determine the number of audio frames stored in one pack in order to generate the packet header when converting the second and later Multiplexing Units to MPEG\_PS packs. Hence, it should be avoided

that it is necessary to analyze the internal structure of the audio stream and then conversion process is complicated.

The Multiplexing Unit is defined above. Encoding to generate a Constrained SESF involves system encoding within the constraints of the above-described Multiplexing Unit.

< Constraints of PES packet headers in a Constrained SESF >

A number of constraints on the field values of the PES packet header in a Constrained SESF are described next.

As shown in Fig. 43, some PES packet header fields allow only fixed values. This is to prevent creating unnecessary processes when converting to different DVD formats. "Unnecessary processes" means processing fields additionally created or deleted by values different from values defined by the DVD format. In other words, the purpose of this PES packet header constraint is to minimize fields added to or deleted from the header during TS2PS conversion.

A value of 0 is permitted for the PES\_packet\_length field when a video stream is stored to the MPEG\_TS.

The PTS\_DTS\_flags field indicates if a PTS or DTS is included.

When the PES packet stores an audio frame, at least one or more audio frames starts in the PES packet, and PTS\_DTS\_flags is set to 10b (to 11b if the DTS is written).

Constraints for sequentially processing by TS packet unit during TS2PS conversion are applied to PES\_extension\_flag and PES\_header\_data\_length. These are shown in Fig. 44.

As shown in Fig. 44, specific values are defined according to the elementary stream type, PES packet location, and encode\_condition value.

Note that VPD in Fig. 44 is the combined byte length of



the PTS field and DTS field in the PES packet. That is,

```
if PTS_DTS_flags = 00b, VPD = 0;  
if PTS_DTS_flags = 10b, VPD = 5;  
if PTS_DTS_flags = 11b, VPD = 10.
```

5           As described above, this constraint is necessary to simplify sequential processing by TS packet unit without forming the packs after determining the payload length of one pack when converting to the DVD Video or VR format.

10           The PES packet header is defined above. An encoder generating the Constrained SESF encodes the system stream within the above constraints.

#### < Constraints on the Tip packet insertion interval >

15           Constraints on the insertion interval of Tip packets inserted to a Constrained SESF are described next.

20           The following relationship must be true for the decoder input time indicated by ATS (ATS1) of the Tip packet, and the decoder input time indicated by ATS (ATS2) of the TS packet storing the video or audio stream input to the decoder first after the Tip packet.

$$\text{ATS1} + T \leq \text{ATS2}$$

$$T = (\text{PS\_pack\_size} * 8 * \text{system\_clock\_frequency}) / \text{PSrate}$$

25           where T is the shortest PS pack transfer period. This shortest transfer period is the shortest period from the start to the end of PS pack input to the system decoder. That is, the above equation shows that the ATS interval of each TS packet must at least be greater than the interval at which PS packs after conversion can be input to the system decoder.

30           The value of T is determined as follows.

          PS\_pack\_size is the byte length of one pack in the

MPEG\_PS generated by TS2PS conversion, the system\_clock\_frequency is the frequency of the reference clock of the MPEG\_PS decoder, and PSrate is the multiplex rate of the MPEG\_PS stream generated by TS2PS conversion.

5                These values are defined as below by the DVD format, and the relationship between ATS1 and ATS2 is therefore as follows.

              PS\_pack\_size = 2048 bytes

              system\_clock\_frequency = 27,000,000 Hz

              PSrate = 10,080,000 bits/second

10            ATS1 + 43885.714... ≤ ATS2

Therefore,

              ATS1 + 43886 = ATS2

15            defines the minimum value of ATS2. The TS2PS conversion described below typically converts a Tip packet to a 2-KB NV\_PCK (in DVD Video conversion) or RDI\_PCK (in DVD VR conversion) pack. However, if the above relationship is not satisfied, the next elementary stream is transferred earlier and may exceed the upper limit of the DVD system transfer rate (10.08 Mbps).

20            An integer number of GOPs are aligned in one SESF capsule. This is to make the SESF capsule correlate to a VOB of the DVD format so that the VOB concept of the DVD format can also be realized in the Constrained SESF. More particularly, a VOB must include an integer number of GOPs according to the DVD format (DVD VR).

25            Video data stored in one SESF capsule must be at least 0.4 second and not more than 1.0 second wide on the playback time base. In addition, the time width on the playback time base of video data stored in the last SESF capsule is greater than or equal to 0.4 second and less than or equal to 1.2 second when the  
30            encode\_condition = 11b (DVD Video mode), and when the

encode\_condition = 01b (DVD VR mode) must be less than or equal to 1.0 second. This is because the SESF capsule becomes a VOB, and must conform to the specific DVD format.

Each Tip packet normally preferably has a 1:1 correlation on the access map used for time-address conversion. This is required so that conversion can start immediately with the VOB units defined by the DVD format during TS2PS conversion, and so that the DSI (Data Search Information) (which provides address information for the adjacent VOB stored in the NV\_PCK) can be generated from the access map when Tip packets are converted to NV\_PCK packs during conversion to the DVD Video format. The DSI can be calculated insofar as the access map stores the playback time (part or all of the AV playback time information immediately after the Tip packet according to FVFPST) for each Tip packet and recording address of each Tip packet, and the number of Multiplexing Units stored between two consecutive Tip packets is known. This is achieved by imposing the following constraints.

It should be noted that all Tip packets need not be pointed to from the access map. For example, AV data following the last Tip packet in a Constrained SESF does not contain playback time length information nor have a next Tip packet, is thus different from other Tip packets and is therefore handled differently. In this case, no particular adverse affect on playback and conversion even if the last Tip packet is not registered in the access map, and thus it can be handled in an exceptions process in consideration with the device implementation.

A total thirty-two packets not associated with a Multiplexing Unit are inserted between two consecutive Tip packets. This is because it is necessary to determine how many packs there will be in a VOB when converted to a DVD format using the access

map during TS2PS conversion. (The number of packets need not be limited to 32, but there must be some specific number of packets. Because the number of TS packets following a Tip packet can be determined from address information of the Tip packet in the access map, the number of packs included in a VOBU when converted to a DVD format can be determined if the number of packets that are not Multiplexing Units, is known. This is important. This information may be described in MNF or MakersPrivateData in each Tip packet.)

Furthermore, the reason there are 32 packets is as follows. It could be sufficient that there are at least 31 PAT, PMT, PCR, and SIT packets between two consecutive Tip packets, because: the PAT, PMT packets describing the MPEG\_TS program configuration data must be embedded at least once every 100 msec; a SIT packet storing specific information for each program must be embedded at least once every 1 second; the PCR packet storing the PCR (program clock reference) establishing the decoder reference time must be embedded at least once every 100 msec; Null packets not belonging to any Multiplexing Unit can be freely added; and the Tip packet insertion interval is 1.0 second or less on the AV data playback time base. Therefore, count of the VOBU pack can be determined from the access map by inserting PAT, PMT, PCR, and SIT packets between two consecutive Tip packets according to these defined times, and adding Null packets until there are 32 packets.

Consider, for example, the number of packs after conversion when a Tip packet is inserted at 0.5 second intervals and there are 1209 TS packets following a Tip packet identifiable from the access map. In this case there is a total of 15 (=5+5+5) PAT, PMT, and PCR packets, 1 SIT packet inserted after this Tip packet, and 16 Null packets inserted to achieve a total 32 packets. When this is then converted to DVD format, the Tip packet is converted to

an NV\_PCK (when converted to DVD-Video) or RDI\_PCK (when converted to DVD VR) as one pack, and one Multiplexing Unit (11 TS packets) is converted to one pack, respectively. The count of VOBUs can therefore be denoted as

5            $1 + (\text{number of Multiplexing Units}).$

The number of Multiplexing Units is

$(\text{number of TS packets following that Tip packet} - 33) / 11.$

In this example, therefore, there are

$1 + ((1210 - 33) / 11) = 1 + 107 = 108.$

10       It thus can be determined that the VOBUs have a total of 108 packs. If the number of packs in each VOBUs and the presentation start time information is known, the DSI packet of the NV\_PCK required for conversion to DVD Video can be generated very quickly.

15       The constraints on the Tip packet insertion interval are as described above. The encoder generating the Constrained SESF encodes the system stream within the above constraints.

< Constraints on decoder control >

20       Constraints on decoder control (buffer management) of Constrained SESF are described next below.

25       A Constrained SESF must be generated to satisfy the standard of T\_STD that is the decoder reference model for an MPEG\_TS. This means that the Constrained SESF can be decoded by a set-top box, for example, having a T\_STD conforming decoder if the stream types match.

30       The MPEG\_TS standard decoder model T\_STD and the MPEG\_PS standard decoder model P\_STD are substantially the same in operation and processing capabilities, but the audio stream input rate to the decoder differs. More specifically, the transfer rate of the T\_STD from the transport buffer before the audio decoder to the audio

buffer is 2 Mbps (except for AAC) (see Fig. 18). The P\_STD, however, inputs each stream to the decoder at the system rate, which with DVD is 10.08 Mbps.

5 This means buffer management of a Constrained SESF and DVD format cannot be the same.

The same buffer management thus cannot be used with an MPEG\_TS and MPEG\_PS. However if the SCR (System Clock Reference) indicating the decoder input time of the pack after conversion can be calculated using the ATS added to each TS packet while avoiding system encoding with re-consideration of buffer management during the conversion from a Constrained SESF to DVD format, very quick and easy conversion can be achieved. Calculating the SCR using the ATS is described in detail further below.

10 Furthermore, the Constrained SESF of the present invention must be encoded so as to assure that it conforms to the T\_STD and also that the MPEG\_PS generated by the conversion method described further below conforms to P\_STD.

15 More specifically, the Constrained SESF is a stream encoded to a MPEG\_TS so that it also conforms to the P\_STD after conversion to an MPEG\_PS.

20 These are the constraints on Constrained SESF buffer management. It should be noted that a normal SESF is simply encoded to conform to the T\_STD without considering these constraints.

25 Examples of MPEG\_TS and MPEG\_PS that do not conform to the standard T\_STD and P\_STD models are described below.

First, an example of a MPEG\_TS self-encoded such that it can be converted to an MPEG\_PS but does not conform to the T\_STD model is shown in Fig. 45. Stream TS1 is an MPEG transport stream applied with system-encoding to conform with the T\_STD model.

30 Stream TS2 is an MPEG transport stream that does not conform to the

T\_STD model. More specifically, in the stream TS2, the values of ATS [47] to ATS [57] are set above the transfer rate allowed for MPEG\_TS audio data. The audio transport buffer thus overflows (Fig. 18) and the stream does not conform to the T\_STD model. In stream TS1, however, the values of ATS [47] to ATS [57] are set within the transfer rate allowed for MPEG\_TS audio data. This stream can therefore be correctly converted to a P\_STD conforming MPEG program stream PS1 using the SCR conversion equation described below. Furthermore, while stream TS2 does not meet the T\_STD standard, PS1 can be generated by conversion using the below SCR conversion equation. For conversion from stream TS2 to MPEG\_TS conforming with a T\_STD, the audio packet transfer time interval specified by ATS [47] to ATS [57] must be increased so that a transport buffer overflow does not occur.

Figs. 46A and 46B shows an example in which the T\_STD model is satisfied but the MPEG\_PS converted from an MPEG\_TS does not satisfy the P\_STD model. Stream TS3 is an MPEG transport stream, and stream PS3 is an MPEG program stream converted from MPEG transport stream TS3. Fig. 46B shows the change in the state of a buffer for video data for each stream during decoding. The PES #1 picture is decoded at time SCR [2], and the PES #2 picture is decoded between SCR [4] and SCR [5]. As shown in Fig. 46B, transfer of TS packet data in transport stream TS3 is completed by the time picture data in PES #1 and PES #2 is decoded. With program stream PS3, however, V\_PCK #1 data transfer for PES #1 is in time, but transfer of V\_PCK #4 for PES #2 data is late for decoding and a buffer underflow occurs because decoding starts while the data transfer is in progress. The requirements of the P\_STD model are therefore not met. This can be avoided by shifting the value of the ATS field (ATS [14], ATS [25], ATS [36]) for each TS packet

converted to V\_PCK #2 to V\_PCK #4 so as to be temporally earlier, so that transferring the MPEG\_TS PES #2 picture data is completed earlier.

5     < ATS-SCR conversion >

Calculation method of the SCR of PS packet when converting a Constrained SESF stream to a program stream is described below. The SCR must be calculated in order to generate a new pack, and is therefore necessary only when converting Tip  
10     packets and the first TS packet in a Multiplexing Unit.

The structure of a Constrained SESF stream is as shown in Fig. 14C. A PCR packet storing reference time information (program clock reference PCR) is appropriately inserted to a TS packet, and this can be used to reset the decoder reference time STC  
15     (system time clock) at an appropriate time interval. Each TS packet also contains an ATS storing the relative transfer time information between each TS packet. Therefore, TS packets output after the TS packet storing the PCR are input to the decoder at a timing determined from the PCR and ATS indicating the relative transfer  
20     time between TS packets. In other words, the decoder input time (the "calculated\_PCR" below) of each TS packet can be generated for TS packets from the TS packet storing the PCR. If no TS packet stores the PCR, information equivalent to the PCR can be extracted to the management information.

25     Fig. 47 shows the relationship between the calculated\_PCR and SCR when converting a Constrained SESF to MPEG\_PS, i.e., a head of the SESF capsule shown in Fig. 80. The ATS assigned to each TS packet in ascending order from the stream start is denoted ATS [k]. The PCR calculated in order of appearance for the  
30     first TS packet in a Multiplexing Unit is denoted calculated\_PCR [i]



( $i = 0, 1, 2, \dots$ ). The SCR of the pack after conversion is likewise denoted SCR [ $i$ ].

As noted above, video stream transfers are constrained by the maximum transfer rate of 15 Mbps (in the case of MP@ML, the transfer rate from the multiplexer buffer to the video buffer does not exceed 15 Mbps) and the audio stream input rate is lower than the video transfer rate. (Except for AAC, the transfer rate from the transport buffer to the audio buffer does not exceed 2 Mbps.) Multiplexing units storing audio data are therefore different from Multiplexing Units storing video data and are transferred at a lower rate. Therefore, if the video data transfer rate is raised to near the 9.8 Mbps maximum rate of the DVD format, TS packets of video data must be transferred at a rate above the DVD transfer rate (10.08 Mbps) in order to assure sufficient time for audio data transfers which occur at a lower rate and therefore take more time.

That the transfer time differs in Constrained SESF and the DVD format will be known from Fig. 47.

The following relationship must be true for the decoder arrival time (calculated\_PCR) of the first TS packet in a Multiplexing Unit or Tip packet, and the SCR of the pack after that packet is converted.

$$\text{SCR}[0] = \text{calculated\_PCR}[0]$$

$$\text{SCR}[i] = \max(\text{SCR}[i-1] + T, \text{calculated\_PCR}[i]) \quad (i = 1, 2, 3, \dots)$$

$$\text{calculated\_PCR}[i] = \text{PCR\_tip} + (\text{ATS}[i] - \text{ATS\_tip} + \text{WA} * \text{BS})$$

$$T = \text{PS\_pack\_size} * 8 * \text{system\_clock\_frequency} / \text{PSrate}$$

where PCR\_tip and ATS\_tip are the PCR value and the ATS of the Tip packet immediately before the converted Multiplexing Unit. WA indicates how many times overflow occurred (described further below) in a range between ATS\_tip and the ATS (ATS [ $i$ ]) assigned to the

first TS packet in the  $i$ -th Multiplexing Unit. BS denotes the amount of one overflow in ATS.  $\max(a,b)$  is a function for selecting the greater of  $a$  or  $b$ .

In the SCR  $[i]$  ( $i = 0, 1, 2, 3, \dots$ ) relation,  
5 PS\_pack\_size is the byte length of one pack in the MPEG\_PS generated by the TS2PS conversion as noted above, system\_clock\_frequency is the frequency of the MPEG\_PS decoder reference clock, and PSrate is the multiplex rate of the MPEG\_PS generated by TS2PS conversion. That is,

10 PS\_pack\_size = 2048 bytes  
system\_clock\_frequency = 27,000,000 Hz  
PSrate = 10,080,000 bits/second

There are, therefore, two patterns for transferring packs after the first pack: transferring the pack after a minimum  
15 transfer time determined by the transfer rate passes from the transfer time of the one preceding pack, or transferring the pack at the decoder input time of the first TS packet in the pack. For pack transfers at a time before the time when the video data is converted to the DVD format, packs are transferred at the minimum transfer  
20 time interval noted above. For example, when packs are transferred in a time band preceding video data conversion to the DVD format, packs are transferred after waiting the minimum transfer time determined by the transfer rate from the time when the preceding pack was transferred.

25 It should be noted that because a Constrained SESF can be edited, the calculated\_PCR [0] may not go to 0 even when recorded with encode\_condition = 11b, if the beginning of the stream is deleted by editing, for example.

30 However, if calculated\_PCR [0] is not zero while encode\_condition = 11b, this problem can be resolved by applying the

following conversion equation only when encode\_condition = 11b.

SCR[0] = 0

SCR[i] = max( SCR[i-1] + T, calculated\_PCR[i] ) -  
calculated\_PCR[0] (i= 1,2, 3, ...)

5       calculated\_PCR[i] = PCR\_tip + (ATS[n] - ATS\_tip + WA\*BS)

T = PS\_pack\_size\*8\*system\_clock\_frequency / PSrate

PTS(DVD-Video) = PTS(Constrained SESF) - calculated\_PCR[0]

DTS(DVD-Video) = DTS(Constrained SESF) - calculated\_PCR[0]

As described above, ATS[n] and WA are ATS value of first  
10 TS packet in i-th Multiplexing Unit and number of overflows based on  
ATS\_tip, respectively.

In other words, to conform to the DVD Video format, SCR  
[0] is set to 0, values of subsequent SCRs are offset values, and  
all PTS and DTS in the DVD Video stream are offset by a uniform time  
15 of calculated\_PCR [0] using the result of the above conversion  
equation offset time calculated\_PCR [0].

By thus uniformly offsetting the time information of the  
stream, conversion to the DVD Video format while keeping  
encode\_condition = 11b is possible even when the beginning of the  
20 Constrained SESF (encode\_condition = 11b) has been deleted.

PTS and DTS values may be converted during conversion to  
the DVD Video format, but this can be easily achieved by  
sequentially processing the TS packet units.

The SCR is calculated from the ATS based on the above  
25 equation during TS2PS conversion. The program stream output by TS2PS  
conversion must conform to the P\_STD model as noted above, and this  
means that SCR values are restricted to a particular range. The ATS  
values assigned to each packet of a Constrained SESF must therefore  
be set according to the ATS-SCR relation shown above.

< Elementary stream constraints >

Constraints on the elementary streams of a Constrained SESF are described next.

5 Because re-encoding the elementary streams imposes an extremely heavy burden on the encoder, only MPEG-2 Video is allowed for video data while AC-3, MPEG-1 Audio, and LPCM are allowed for audio data.

10 The Constrained SESF described here excludes LPCM, however. This is to avoid the danger of needing to re-encode the elementary stream when LPCM uses a quantization rate of 20 bits or more, and to simplify buffer management by reducing the amount of audio data for which the transfer rate cannot be raised. If 16-bit LPCM is used, however, there is no particular need to exclude LPCM audio.

15 Streams permitted for the Constrained SESF described here are MPEG-2 Video for the video data, and two types of audio data, AC-3 and MPEG-1 Audio.

20 In normal SESF which is not Constrained SESF, encoding of audio data is not limited to the above. Encoding method such as AAC (Advanced Audio Coding) which is used in BS digital broadcasting can be used.

Elementary stream attributes when encode\_condition = 11b are shown in Fig. 48.

25 Because the attributes shown in the figure are set to assure interchangeability at the elementary stream level between DVD Video and DVD VR, a Constrained SESF (encode\_condition = 11b) conforming to these attributes does not require elementary stream re-encoding when converted to DVD Video or DVD VR formats, and high speed conversion is therefore possible.

30 Elementary stream attributes when encode\_condition = 01b

are shown in Fig. 49.

Because the attributes shown in the figure are set to assure interchangeability at the elementary stream level with DVD VR, a Constrained SESF (encode\_condition = 01b) conforming to these attributes does not require elementary stream re-encoding when converted to DVD VR format, and high speed conversion is therefore possible.

Notes 1 to 4 in Fig. 48 and Fig. 49 are described below.

Note 1: This attribute cannot change within the same VOB.

Note 2: This attribute can change in the TS packet storing the first elementary stream following the Tip packet. In other words, it can change only in the first video or audio TS packet in an SESF capsule.

Note 3: sequence\_end\_code cannot be inserted between sequence\_header fields having the same horizontal\_size, vertical\_size, and aspect\_ratio\_information.

Note 4: This attribute can change within the same VOB for monaural, stereo, and dual monaural.

Constraints relating to the elementary streams of a Constrained SESF are described above.

Adding the encoding conditions described above makes it possible to generate a Constrained SESF that can be easily and quickly converted to a DVD format.

< DVD Video and DVD VR format after conversion >

The field settings of the DVD Video and DVD VR formats to which the Constrained SESF is to be converted are described next.

<DVD Video format>

A stream conforming to the DVD Video standard is

described briefly first below. The DVD Video stream format is described in detail in "DVD Specifications for Read-Only Disc, Part 3, VIDEO SPECIFICATIONS."

The stream structure of the DVD Video format is shown in Fig. 50. As shown in the figure each stream contains multiple VOBs and each VOB contains an integer number of VOBUs. A VOBU includes an integer number of packs, starting with a NV pack (V\_PCK) followed by a video pack (V\_PCK) an audio pack (A\_PCK). Unlike a normal DVD pack, the NV\_PCK contains two packets. These packets are called the PCI (Presentation Control Information) and DSI (Data Search Information) packets, respectively. The playback control information for the corresponding VOBU is stored to the PCI packet. Information useful for special playback modes, such as the relative positions of the VOBU to neighboring VOBU, is stored to the DSI packet. These fields are described next below in conjunction with how the field values are determined.

Fig. 51 shows the structure of NV\_PCK PCI data. The PCI data includes PCI\_GI (PCI General Information) storing general information for PCI, NSML\_AGLI as angle information for non-seamless presentation, HLI as information for adding highlighting to menus and buttons, and RECI storing the International Standard Recording Code (ISRC).

When converted from Constrained SESF, NSML\_AGLI and HLI store a value indicating an invalid.

The ISRC field can store a value indicating an invalid or a ISRC code as it is, but this field is irrelevant to conversion from Constrained SESF and further description is therefore omitted. The only field that a problematic with respect to creating PCI data from a Constrained SESF is therefore the PCI\_GI field.

Fig. 52 shows the structure of the PCI\_GI field in

NV\_PCK. Note that calculation methods are described below only for those fields that must be calculated during conversion from a Constrained SESF.

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5                NV\_PCK\_LBN (the relative address of NV\_PCK in the VOBS file) can be determined by the data recording apparatus which counts each pack number during conversion.

              VOBU\_CAT (information of the analog copy protection state) can be obtained from the display\_and\_copy\_info of the Tip packet corresponding to the NV\_PCK.

10              VOBUS\_PTM (presentation time information for the video field presented first in the VOB) can be calculated from the FVFPST of the Tip packet corresponding to the NV\_PCK.

              VOBU\_E\_PTM (time information when presentation of video data in the VOB ends) can be obtained from the presentation time information written to the next entry in the access map, or it can be generated by analyzing the video stream of the VOB and calculating the time at which video presentation ends.

              VOBU\_SE\_PTM (time information when presentation of video data in the VOB ends according to the sequence\_end\_code field) is filled with "0x00000000" in all VOBs before the last VOB, because the sequence\_end\_code is only permitted in the last VOB and the middle VOB therefore do not contain the sequence\_end\_code. VOB\_SE\_PTM is set to the same value as in VOB\_E\_PTM in only last NV\_PCK having sequence\_end\_code in the last VOB .

              C\_ELTM is the time difference between the presentation time of the first video frame presented in a cell storing NV\_PCK and the video frame first presented in the VOB, and must be expressed with frame precision. C\_ELTM can be calculated as needed by the data recording apparatus during the conversion process using the FVFPST

of the corresponding Tip packet and the presentation time information of the video frame presented at the beginning of a CELL.

NV\_PCK PCI data can thus be generated as needed by VOB unit during conversion as described above.

5                Fig. 53 shows the DSI structure of the NV\_PCK. As shown in Fig. 53 the DSI data field includes: DSI\_GI (Data Search Information General Information) storing general DSI information; SML\_PBI (Seamless Playback Information) storing recording address and playback information needed for seamless presentation between  
10        VOBs; SML\_AGLI (Angle Information for seamless) storing location information needed for seamless presentation between different angles and so on; VOB\_U\_SRI (VOB Unit Search Information) storing the recording address of VOB adjacent to a particular VOB; and SYNCI (Synchronous Information) enabling synchronous presentation of video  
15        with audio/subpictures.

When converted from a Constrained SESF, SML\_AGLI stores information indicating invalid.

Fig. 54 shows the DSI\_GI structure of an NV\_PCK. Note that calculation methods are described below only for those fields  
20        that must be calculated during conversion from a Constrained SESF.

NV\_PCK\_SCR (the SCR of the NV\_PCK) is deduced from the SCR deduced from the ATS of the Constrained SESF by the method described further below.

25        NV\_PCK\_LBN (relative address of the NV\_PCK in the VOB file) is obtained in the same manner as the PCI data.

VOBU\_EA (relative address from the NV\_PCK to the last pack in the VOB) can be calculated from the access map. As described above, the number of packets not belonging to a Multiplexing Unit between two consecutive Tip packets is known  
30        (fixed). Therefore, the number of TS packets to the next entry (the



next Tip packet) can be calculated from the access map. The number of TS packets in that TS packet not belonging to a Multiplexing Unit then subtracted, and the difference is then divided by 11 to determine the number of packs formed after the NV\_PCK. The number of  
5 packs generated after conversion can be counted and written to the NV\_PCK derived from the last Tip packet or to all NV\_PCK.

VOBU\_1STREF\_EA (relative address in the VOB from NV\_PCK to the last pack in the first referenced picture), VOB\_2NDREF\_EA (relative address in the VOB from NV\_PCK to the last pack in the  
10 second referenced picture), and VOB\_3RDREF\_EA (relative address in the VOB from NV\_PCK to the last pack in the third referenced picture) can be determined without analyzing to the video stream layer if the Tip packet PES\_info field is referenced during TS2PS conversion.

15 PES\_info stores the picture\_coding\_type indicating the type of encoding applied to the picture stored in each video PES packet. A PES packet with a picture\_coding\_type of 01b or 10b stores a reference picture as defined in the DVD Video standard.

It is therefore possible to reference the PES\_info field  
20 during TS2PS conversion to determine if the PES packet being converted stores a reference picture, and the pack in which said converted PES packet ends becomes the last pack of the reference picture.

Because the last pack of a reference picture can be  
25 identified during conversion, it is also possible while generating the VOB to determine in which pack the first, second, and third reference pictures end, and write a relative address to the end of each said picture in the VOB\_1STREF\_EA, VOB\_2NDREF\_EA, and VOB\_3RDREF\_EA fields of the first NV\_PCK in the VOB.

30 Alternatively, during conversion of SESF Capsule, with

reference to PTS\_DTS\_flags of PES packet storing video data, storage of the reference picture may be determined serially to calculate these values. For example, if PTS\_DTS\_flags is 11b, the reference picture is determined to be stored, while if PTS\_DTS\_flags is 10b, the non-reference picture is determined to be stored.

VOBU\_VOB\_IDN (the ID number of the VOB to which the VOBU belongs) should be obtainable by the data recording apparatus during conversion. When one Constrained SESF is being converted, VOB segmentation due to the stream conditions, such as an attribute change, is prevented and the same ID number can be assigned by setting the Constrained SESF encode\_condition to 11b.

Like VOBU\_VOB\_IDN, VOBU\_C\_IDN (the ID number of the CELL to which the VOBU belongs) is set by the data recording apparatus during conversion, and is not related to the stream. If the CELL is intentionally segmented based on the PGC information or other management information for the Constrained SESF, a number determined by the segmentation is simply assigned.

C\_ELTM is the time difference between the presentation time of the first video frame presented in a cell storing NV\_PCK and the video frame first presented in the VOBU, and must be expressed with frame precision. C\_ELTM is the same as the C\_ELTM written to the PCI data.

Each field of the DSI\_GI field in the NV\_PCK can thus be continuously generated by VOBU unit during conversion as described above.

Fig. 55 shows the structure of the SML\_PBI field in NV\_PCK. Note that calculation methods are described below only for those fields that must be calculated during conversion from a Constrained SESF.

VOB\_V\_S\_PTM (presentation time of the first video frame

presented in the VOB to which NV\_PCK belongs) can be determined from the FVFPST of the first Tip packet.

VOB\_V\_E\_PTM (video presentation end time in the VOB to which NV\_PCK belongs) can be set anytime by analyzing the stream after the last Tip packet in the part of the Constrained SESF selected for conversion before the actual TS2PS conversion and obtaining the end presentation time of video data.

It is thus possible to calculate the fields of SML\_PBI of NV\_PCK before conversion. It is enough to use that value during the conversion.

As noted above VOBU\_SRI can be calculated using the access map, and further description thereof is thus omitted here.

Furthermore, VOBU\_SRI is written completely within each cell and thus cannot be determined if the cell is not defined. Therefore, a recorder that records in the DVD Video format in real-time cannot create cells at any desired interval and thus suffers from degraded editing and playback performance. When converting from a Constrained SESF, however, cells can be defined as periods specified by the user and converted using the method described above, chapters can be created as intended by the user, and a play list that starts playback from a user-defined point can be created conforming to the DVD Video format.

Fig. 56 shows the structure of the SYNCI field of NV\_PCK. Note that calculation methods are described below only for those fields that must be calculated during conversion from a Constrained SESF.

A\_SYNCA0 is the relative address of a pack storing a primary audio pack and storing the audio frame presented simultaneously to or immediately after VOBU\_S\_PTM. It can be determined using the PES\_info in the Tip packet without analyzing

the stream during TS2PS conversion.

Whether a PES packet stores primary audio can be determined by reading the `stream_identifier` of the `PES_info`, and at the next `sync_presentation_flag` it is possible to determine whether there is an audio frame presented simultaneously to or immediately after `VOBU_S_PTM` in the audio frame contained in the PES packet. Therefore, if the PES packet contains primary audio and the `sync_presentation_flag = 1b`, the address from the `NV_PCK` to the pack storing the PES packet can be written during TS2PS conversion.

It should be noted that there is no guarantee that the `sync_presentation_flag = 1b` will be set in one audio pack of the VOB. If the encoder multiplexes the audio first, the audio pack presented simultaneously to or immediately after `VOBU_S_PTM` of the VOB could be stored in the preceding or the following VOB.

The value set to the `A_SYNCA0` field must therefore be determined during conversion with a correct understanding of the sequential relationship between the PES packet of the primary audio (the `sync_presentation_flag = 1b`) and the subsequently generated `NV_PCK`.

To eliminate this process the Constrained SESF can be system encoded so that the audio data presented simultaneously to or just after the `FVFPST` written to the first Tip packet in the SESF capsule is also stored in the same SESF capsule.

By using these definitions a process for detecting audio data synchronized to `VOBU_S_PTM` (`FVFPST`) outside the VOB (SESF capsule) can be eliminated.

`A_SYNCA1` is the relative address of a pack storing a secondary audio and storing the audio frame presented simultaneously to or immediately after `VOBU_S_PTM`, and can be determined using the same method as `A_SYNCA0`.

Except for A\_SYNCA, it is thus possible to sequentially generate DSI data of NV\_PCK by VOB unit during conversion.

An example of NV\_PCK generation is as shown in Fig. 82.

5 <DVD Video Recording format>

Field settings during conversion to the DVD Video Recording (VR) stream format are described next below.

The DVD VR stream is described briefly below. Note that the DVD VR stream format is described in detail in "DVD  
10 Specifications for Rewritable/Re-recordable Discs, Part 3, VIDEO RECORDING."

Fig. 57 shows the stream structure of the DVD VR format. As shown here each stream includes multiple VOBs, and each VOB contains an integer number of VOBUs. A VOB includes an integer  
15 number of packs, starting with an RDI\_PCK followed by a video pack (V\_PCK) and an audio pack (A\_PCK). Unlike a normal pack, the RDI\_PCK contains presentation and copy control information, and manufacturer-specific information. The fields contained in the RDI\_PCK are described below together with how the field values are  
20 determined.

As shown in the figure, the RDI\_PCK payload data (RDI Unit) includes: RDI\_GI (Real-time Data Information General Information) storing general information of RDI, DCI\_CCI (Display Control Information and Copy Control Information) storing  
25 information used for display and copy control, and MNFI (Manufacturer's Information) storing manufacturer-specific information.

The RDI\_GI field contains a VOBU\_S\_PTM field. Only this field is variable and the other field values are fixed.

30 VOBU\_S\_PTM has the same format as the FVFPST written to

the corresponding Tip packet in the transport stream before conversion, and the FVFPST value can therefore be simply copied to the VOBUS\_PTM field.

5 DCI\_CCI has the same format as the display\_and\_copy\_info field of the Tip packet, and the display\_and\_copy\_info value can therefore be simply copied to the DCI\_CCI field.

A specific manufacturer ID is allocated only when the maker\_ID written to the Tip packet is identical to the manufacturer ID of the data recording apparatus, and the manufacturer-specific information is copied to the MNFI field. However, if the maker\_ID in  
10 the Tip packet is the ID for a different manufacturer, or the maker\_ID is invalid, the RDI pack can be generated by writing invalid data to the MNFI field.

It is possible that part of the data written to the Tip  
15 packet is invalid. In this case a flag (an invalidation flag) indicating that there is invalid data in the Tip packet should be set. If this invalidation flag is set to ON, the flag must be updated after updating the invalid data in the Tip packet to the most recent data.

20 As an example of this, considered can be a case where the most recent CCI data and a TS packet CCI data invalidation flag are present in the ATS (4B) of each TS packet.

In this case it is necessary to determine if the invalidation flag is set during TS2PS conversion. If it is, it is  
25 necessary to convert to an RDI\_PCK using data updating the CCI data in the display\_and\_copy\_info field with the CCI flag of the ATS.

RDI\_PCK can thus be sequentially generated using only the corresponding Tip packet (and ATS thereof).

30 Fig. 58 is a flow chart of the above RDI\_PCK generation process.

In a RDI\_PCK (or NV\_PCK), the system header includes fixed-value fields. Details of the system header are shown in Fig. 61. The packet header and private header stored to the RDI\_PCK are shown in Figs. 62A and 62B, respectively. Because these headers  
5 include fixed-value fields as shown in the figures, they can be easily generated.

Fig. 59 is a flow chart of a process for generating PS packs from TS packets (Multiplexing Unit) storing AV data.

As shown in the figure, TS packets of a Constrained SESF  
10 storing AV data are converted using one Multiplexing Unit as the unit of processing to 2KB packs of an MPEG\_PS storing AV data. This is further described below following the steps of this process.

(Step S4200): One TS packet is read from the conversion starting point of the Constrained SESF stream.

15 (Step S4201): Whether the read TS packet stores AV data and is the first TS packet in a Multiplexing Unit is determined.

Whether AV data is stored is determined by reading the PID value of the TS packet declared in the PMT to store AV data. The TS packet is determined to be at the beginning of a Multiplexing  
20 Unit when the preceding TS packet is a Tip packet, PSI/SI packet, or PCR packet and the TS packet following immediately thereafter stores AV data. Because a Tip packet is expected at a conversion starting point, whether it is at the beginning of a Multiplexing Unit can be determined by sequentially reading the TS packet (that is, the first  
25 TS packet storing AV data immediately after a Tip packet is always at the beginning of a Multiplexing Unit). If the TS packet is determined to not be at the beginning of a Multiplexing Unit, or if conversion does not start from a Tip packet and the determination cannot be made, control loops back to step S4200 to read the next TS  
30 packet. Control moves to the next step after the beginning of a

Multiplexing Unit is found.

(Step S4202): Using the ATS assigned to the TS packet at the beginning of the Multiplexing Unit, the time (calculated\_PCR) at which the MPEG\_PS pack to which the TS packet is converted will be input to the decoder is calculated. The PCR is calculated as described above. Once the PCR is calculated the SCR can be determined by the method described above, and the pack header shown in Fig. 60 is completed. This is because except for the SCR only fixed values are permitted in the pack header.

(Step S4203): The packet header and private header are determined.

The packet header is created based on the PES packet header of the Constrained SESF. The form of the packet header must satisfy the field values shown in Fig. 63. This is because conversion from the Constrained SESF will not be determined uniformly if field values that will change the header length are not set, and buffer management may be affected. Field not shown here are fixed values and are therefore not listed.

Individual field values of the PES packet header are determined specifically with the Constrained SESF in order to minimize the processing required for PES packet header (MPEG\_TS) to packet header (MPEG\_PS) conversion.

If the PES packet is large relative compared to the size of one pack, one PES packet will be converted to plural packs. In this case revisions to the packet headers of the second and subsequent packs include setting PTS\_DTS\_flags in the first packet header generated from the PES packet to 00b, the PES\_extension\_flag to 0b, adjusting the stuffing\_byte length, and correcting PES\_header\_data\_length.

The private header is required when a non-MPEG stream is



stored, and is therefore required in packs storing NV\_PCK, RDI\_PCK, AC-3, or LPCM.

Fig. 64 shows the private header of an AC-3. Of the fields shown in the figure, only the `number_of_frame_headers` field requires calculating during TS2PS conversion according to the Constrained SESF Multiplexing Unit definition. Because this field specifies the number of AC-3 audio frames stored in the pack, the field value can be easily calculated from the `PES_packet_length` for fixed-rate AC-3, for example, because the byte length of one audio frame is calculable from the bit rate and the value is a fixed length.

It should be noted that the `PES_header_data_length` of the PES packet header of a Constrained SESF is stuffed with an extra 4 bytes by the AC-3 private header (4 bytes). (See Fig. 44.) By thus estimating before conversion the header length after conversion and shifting the payload position, sequential process in units of TS packet can be easily done.

As described above, the first packet header is generated by correcting a part of the PES packet header, the second and later packet headers is generated by correcting a part of the first packet header, and the private header is inserted only for streams not complying with MPEG standard. The packet header and private header can thus be generated.

(Step S4204): Once the private header is generated, the PS pack payload is filled from the beginning thereof by simply copying data from the TS packet payload.

(Steps S4205 to S4207): These steps simply repeat until the Multiplexing Unit (11 TS packets) is completed. However, because it is possible that a Null packet has been inserted, TS packet payload data is copied while the Null packet PID (0x1FFF) is detected.

Preferably it is defined that only the TS packet storing the last data of the PES packet has an adaptation field. This makes reading the payload data easier because TS packets other than TS packet storing the last data of PES packet in Constrained SESF  
5 always store 184 bytes of payload data.

(Step S4208): When all Multiplexing Unit payload data has been copied, the byte length of the resulting pack is calculated to confirm if a byte length is 2048 bytes. Pack generation ends if there are 2048 bytes. If the pack contains less than 2048 bytes,  
10 control steps to S4209.

(Step S4209): If the pack does not contain 2048 bytes, a padding packet is added to the end of the payload to a total of 2048 bytes.

The conversion process thus proceeds from a Multiplexing  
15 Unit storing AV data. This process repeats only if a Multiplexing Unit is detected until processing the part of the Constrained SESF selected for conversion ends.

The result of the above conversion process applied to packs of different types is described next below.

20

<Conversion to a video pack (V\_PCK)>

Figs. 65A and 65B show the conversion from a Constrained SESF to MPEG\_PS. As shown in Fig. 65A, one video PES packet is normally larger than 2 KB, and is therefore segmented to plural  
25 Multiplexing Units and multiplexed to a Constrained SESF.

Based on the Constrained SESF definition each Multiplexing Unit other than the last Multiplexing Unit in a video PES packet is filled with the greatest possible amount of video PES packet data. Every Multiplexing Unit other than the last  
30 Multiplexing Unit therefore stores 2024 bytes (= 184 x 11 bytes) of

data.

Using this definition makes it possible to predefine such fields as the PES\_packet\_length and stuffing\_byte of each pack at TS2PS conversion.

5           The last Multiplexing Unit storing data for one video PES packet may fill the remaining data capacity with the adaptation field and Null packets to form one complete Multiplexing Unit, or store data of the next PES packet for efficient data transfer (for increasing amount of data stored to the converted MPEG-PS pack).

10           However, in consideration of facility of conversion to DVD, only I-picture in SESF capsule is located from the beginning TS packet in the Multiplexing Unit storing the first video data in the SESF capsule. P-picture and B-picture may not be located from the beginning of the Multiplexing Unit as describe above.

15           As shown in Figs. 65A and 65B, the following three types of Multiplexing Units are used to form one video PES packet: the first Multiplexing Unit storing the first data in the PES packet (MU #1 in the figures); Multiplexing Units (MU #n where  $n = 2, 3, \dots N-1$ ) storing data in the middle of the PES packet; and the  
20 Multiplexing Unit (MU #N) storing the last PES packet data.

The structure of the packs corresponding to these Multiplexing Unit types in the MPEG\_PS stream resulting from TS2PS conversion is shown in Fig. 65B.

25           The pack converted from MU #1 always contains at least 10 bytes of empty space, and padding packets are therefore inserted at the end when the pack is generated.

30           This is because the DVD format specifies that stuffing bytes (last field of the packet header) are added to a total 2048 bytes when there is a space of 7 bytes or less in the pack, and padding packets are added if the space is 8 bytes or larger.

One stuffing byte is added to the packs converted from MU #n to complete each pack.

The pack converted from MU #N normally has a space of 8 bytes or larger, and a padding packet is therefore inserted.

5

<Conversion to an audio pack (A\_PCK)>

Figs. 66A and 66B shows conversion from Constrained SESF to MPEG\_PS. As shown in Fig. 66A, one audio PES packet (storing one or more audio frames) is smaller than one Multiplexing Unit.

10

Because one audio PES packet will fit in one Multiplexing Unit, complex conversion is not required as it is for a video PES packet. More specifically, packs to which padding packets are added should always be generated as shown in Fig. 66B.

15

Furthermore, because PES\_packet\_length does not change with TS2PS conversion, only simple calculations are required for conversion. These include appropriately setting the stream\_id when converting MPEG-1 Audio, and generating the AC-3 private header.

20

As also shown in the figure, buffer management can be simplified by minimizing the audio data transfer time, which is the greatest factor complicating system encoding a Constrained SESF.

25

Because video data and other PSI/SI packets cannot be transferred when audio Multiplexing Units are being transferred, the overall transfer rate drops (i.e., image quality drops), and as the transfer time increases the video data must be transferred that much earlier on the transport stream (thus complicating system encoding). The audio Multiplexing Unit transfer time is therefore preferably as short as possible.

30

In other words, transferring the audio Multiplexing Unit in a shorter time means increasing the audio transfer rate. This is connected to reducing the difference between the allowed audio input

rates, which is a major difference between the T\_STD and P\_STD. A major benefit of this is to also simplify generating a Constrained SESF, which must conform to both decoder models.

5 Fig. 67 shows the audio bit rates allowed in a Constrained SESF and the maximum payload length stored to one audio PES packet when AC-3 and MPEG-1 Audio is stored at each bit rate. Because data longer than the shown byte lengths will not fit in one audio PES packet, padding packets are inserted.

10 (Constraints in PES packet)

Integer number of PES packets including integer number of audio frames may be stored to integer number of Multiplexing Units so as to increase amount of data which can be stored in converted MPEG-PS pack, thus achieving efficiency multiplexing.  
15 However in this case, a problem may occur on PTS calculation during the conversion.

DVD standard specifies that PTS of the first one of audio frames which start in PES packet for audio should be described as PTS in a packet header of a PES packet for audio.

20 In TS2PS conversion, there may be a case in that an audio frame at a head of PES packet after conversion to MPEG-PS (DVD) does not conform with an audio frame at a head of PES packet multiplexed with the constrained SESF before conversion. Accordingly, in the present invention. the multiplexing process is  
25 performed according to the constrained SESF so that the first one of audio frames in PES packet of a pack of MPEG-PS after conversion always includes PTS. Thus it is not necessary to calculate and obtain PTS newly in TS2PS conversion.

30 Accordingly, it is effective to arrange that the first one of complete audio frames in the Multiplexing Unit is the first

one (that is, the audio frame with PTS inevitably recorded) of audio frames in a payload of PES packet in Multiplexing Unit. Therefore, the constrained SESF according to the present invention defines that the first one of complete audio frames in the Multiplexing Unit is the first one of audio frames in a payload of PES packet in the Multiplexing Unit. This definition may also be defined so that an audio frame of which beginning byte starts first in the Multiplexing Unit is the first audio frame in a payload of PES packet in the Multiplexing Unit. The constraint by this definition is one of constraints of the constrained SESF, and thus it is possible to judge if the definition is satisfied by referring to encode\_condition flag.

Fig. 83A is a figure showing MPEG-TS which is formatted in the constrained SESF satisfying the above definition and MPEG-PS which is converted therefrom.

PES packet header of PES packet 411, 412 or 413 includes PTS value (PTS#1, PTS#5 or PTS#8) for the first audio frame (AF#1, AF#5 or AF#8) in audio frames included in each PES packet 411, 412 or 413.

The first Multiplexing Unit (401) includes all data for PES packet 411 and a part of data for PES packet 412.

The first complete audio frame in the first Multiplexing Unit (401) is audio frame #1 which is the first audio frame in the payload of PES packet 411 and thus satisfies the above definition.

Regarding the second Multiplexing Unit (402), the first complete audio frame in the second Multiplexing Unit (402) is audio frame #8 which is the first audio frame in the payload of PES packet 413 and thus satisfies the above definition. It is noted that although the second Multiplexing Unit (402) includes a latter half of audio frame #7 immediately after PES packet header, the latter half of audio

frame #7 is a part of audio frame but is not a complete audio frame. Therefore this is not a condition used for considering the above definition.

5 PES packet header of PES packet 411 included in the first Multiplexing Unit (401) includes PTS value (PTS#1) of the first audio frame #1 of audio frames (AF) following the PES packet header. The second Multiplexing Unit (402) includes PTS value (PTS#8) of the first complete audio frame #8 in audio frames (AF) following the second Multiplexing Unit.

10 When converting the second Multiplexing Unit (402) to MPEG-PS, PTS value stored in PES packet header included in Multiplexing Unit (402), a value of PTS value (PTS#8) stored in PES packet header included in the Multiplexing Unit (402) is copied as it is to PES packet header in the destination MPEG-PS. Thus it is  
15 enough to copy PTS value in PS2TS conversion, thereby simplifying the process.

Next description is made to a case in that PES packet includes video data. As one of constraints of constrained SESF regarding PES packet including video data, it may be defined that  
20 PES packet including I-picture starts from a head of the Multiplexing Unit.

Fig. 83B shows an example satisfying the above definition. In Fig. 83B, PES packet 416 includes I-picture, and PES packet header of the PES packet stores PTS value (PTS#2) of I-  
25 picture. PES packet 416 is located at a head of the Multiplexing Unit (404).

In packs of the converted MPEG-PS, PTS value (PTS#2) stored in PES packet header 421 points out I-picture immediately after the PES packet header 421. The Multiplexing Unit (403) stores  
30 P-picture included in the payload of PES packet 415. The remaining

portion of the Multiplexing Unit is filled with NULL packets to align I-picture to the next Multiplexing Unit (404).

When the Multiplexing Unit (404) is converted to MPEG-PS, a value (PTS#2) of PES packet header in the Multiplexing Unit (404) is copied to PES packet header 421 of MPEG-PS pack. Hence, it is enough to just copy PTS but it is not necessary to calculate PTS, thus simplifying the process.

<TS2PS conversion process>

The TS2PS conversion process is detailed next below with reference to flow charts of Fig. 68 to Fig. 79.

Fig. 68 is a flow chart of the main TS2PS conversion process. This process starts when a user inputs a TS2PS conversion request. The data recording apparatus then seeks the SESF capsule from which conversion starts (S11) and determines if the SESF capsule to be processed is present (S12). If it is not, the process ends. If the SESF capsule is present, an initialization process (S13) and capsule unit process (S14) are run.

The initialization process (S13) is described with reference to the flow chart in Fig. 69. This process sets and initializes the variables and other parameters used in the following process.

Whether a Tip packet has been read is first determined (S21). If a Tip packet has not yet been read, a Tip packet is read (S22). The ATS value of the read Tip packet is then set to variable ATSTip (S23), the PCR value of Tip packet is set to variable PCRTip (S24). Variable MU\_num specifying the number of the Multiplexing Unit being processed is set to 0 (S25), and variable WA indicating how many times an ATS overflow occurred is set to 0 (S26).

The capsule unit process (S14) is described with



reference to the flow chart in Fig. 70. This process starts by reading a TS packet (S31) and then detecting if the read TS packet is a Tip packet (S32). Processing ends if it is a Tip packet. If not a Tip packet, it is determined whether the read TS packet contains an audio packet or video packet (S33). If the read TS packet does not contain an audio packet or video packet, control loops back to step S31, and TS packets are sequentially read until the read TS packet is an audio packet or video packet (S31 to S33 repeat).

When the read packet is an audio or video TS packet, the next 10 TS packets are also read (S34). MU\_num is then incremented (S35). The ATS value of the first TS packet in the Multiplexing Unit is stored to variable ATS[MU\_num] (S36). The byte length of the payload data in the PES packet stored to the Multiplexing Unit is set to payload\_len (S37). The pack unit process is then run (S38).

As shown in the flow chart in Fig. 71, the pack unit process includes an SCR calculation process (S41), pack header process (S42), packet header process (S43), payload process (S44), and padding packet process (S45). These processes are described below.

The SCR calculation process is described with reference to the flow chart in Fig. 72.

This process determines the SCR value of the pack. The first step is to determine whether the Multiplexing Unit is the first Multiplexing Unit in the SESF capsule by referencing variable MU\_num (S51). If it is, the value of ATSTip is set to variable ATS[0] and the value of variable PCRTip is set to variable SCR[0] (S52-S53).

ATS[MU\_num] and ATS[MU\_num-1] are then compared (S55). The ATS value of the first packet in the Multiplexing Unit is stored to ATS[i], and this ATS value indicates the relative transfer timing

referenced to a particular packet. Therefore, the ATS value of each subsequent packet is normally greater than the ATS value of the previous packet. However, because the ATS is generally limited to a finite value expressible with 30 bits, ATS overflow can occur. In this case the ATS value of a certain packet may be smaller than that of the preceding packet. Step S54 monitors this reversal of ATS values to determine when an ATS overflow occurs. If  $ATS[MU\_num]$  is not greater than  $ATS[MU\_num-1]$ , that is, if an ATS overflow occurred, variable WA is incremented (S55).

10           The greater one of  $SCR[MU\_num-1] + T$  and  $(PCRTIP + ATS[MU\_num] - ATSTip + WA \times BS)$  is then set to  $SCR[MU\_num]$  (S56).

The pack header process is described with reference to the flow chart in Fig. 73.

15           This process edits the pack header data in the data structure shown in Fig. 60. The remainder of the SCR divided by 300 is first inserted to SCR\_extension (S61), and the quotient is set to SCR\_base (S62). The program\_mux\_rate is set to "0x6270" (S63), and pack\_stuffing\_length to "000b" (S64). Other fields are edited appropriately to complete the pack header data (S65).

20           The packet header process is described with reference to the flow chart in Fig. 74.

25           This process starts by running a stream ID process for setting the stream ID (S71). Whether Multiplexing Unit contains video data is then determined (S72). When Multiplexing Unit includes video data, it is determined whether the beginning TS packet in Multiplexing Unit includes PES packet header (S73). If the first TS packet of the Multiplexing Unit contains a PES packet header, a video PES packet leading process is run (S74), and a PES packet non-leading process is otherwise run (S75). Whether  
30           the first TS packet of the Multiplexing Unit contains a PES packet

header can be determined by reading the `payload_unit_start_indicator` field of the TS packet header, or by directly detecting if a PES packet header start code is stored.

5 On the contrary, when Multiplexing Unit does not include video data, it is judged if Multiplexing Unit includes PES packet header (S76). When Multiplexing Unit includes PES packet header, audio PES packet leading process is performed (S77), otherwise audio PES packet non-leading process is performed (S78).

10 The stream ID process is described with reference to the flow chart in Fig. 75.

This process sets the value of the `stream_id` field. If the type of the stream being processed is "MPEG-2 Video", the `stream_id` is set to "0xE0" (S81, S82). If the stream type is "AC-3 audio", the `stream_id` is set to "0xBD" (S83, S84). If the stream type is "MPEG-1 Audio" and "primary audio", the `stream_id` is set to "0xC0" (S85, S86, S87). If the stream type is "MPEG-1 Audio" and "secondary audio", the `stream_id` is set to "0xC1" (S85, S88, S89).

The PES packet leading process is described with reference to the flow chart in Fig. 76A.

20 The structure of a PES packet according to the MPEG standard is shown in detail in Fig. 81. This process edits the PES packet fields according to the structure shown in Fig. 81.

First, PES packet header which is the same as the first PES packet header stored in TS packet at a head of Multiplexing Unit is generated as PES packet header of the converted MPEG-PS (S91). Next, `PES_packet_length` is set to the value determined by the following equation (S92).

$$\begin{aligned} \text{PES\_packet\_length} = \\ (3 + \text{PES\_header\_data\_length}) + \text{payload\_len} \end{aligned}$$

30 Then, it is determined whether `PES_extension_flag` is "1"

(S93). When PES\_extension\_flag is "1", the 3 bytes from PES\_private\_data\_flag to P\_STD\_buffer\_size are overwritten with a predetermined value (0x1E60E8) (S94).

5 The video PES packet non-leading process is described with reference to the flow chart in Fig. 76B.

The PES packet header is set to a provisional value (0x000001E007EC800001FF) (S111). It is determined whether a value of (2025 - payload\_len) is between 1 and 8 (S112).

10 If the value of (2025 - payload\_len) is not less than 8, the control goes to Step S116.

If the value of (2025 - payload\_len) is between 1 and 8, PES\_header\_data\_length is set to (2025 - payload\_len) (S113), and PES\_packet\_length is set to a value determined by the following equation (S114).

15 
$$\text{PES\_packet\_length} = (3 + \text{PES\_header\_data\_length}) + \text{payload\_len}$$

Then, stuffing\_byte is filled with stuffing bytes with a length of (2024 - payload\_len) bytes (S115), and the control goes to Step S116.

20 In Step S116, it is determined whether the value of (2025 - payload\_len) is not less than 8. If it is not less than 8, PES\_header\_data\_length is set to 0 (S117), and PES\_packet\_length is set to a value determined by the following equation (S118).

$$\text{PES\_packet\_length} = 3 + \text{payload\_len}$$

25 Then, one byte of stuffing byte is removed from stuffing\_byte (S119).

The audio PES packet leading process is described with reference to Fig. 77A.

30 First, PES packet header which is the same as PES packet header appearing first in Multiplexing Unit is generated as PES

packet header of the converted MPEG-PS (S181). Next, PES\_packet\_length is set to the value determined by the following equation (S182).

$$\text{PES\_packet\_length} =$$

5  $(3 + \text{PES\_header\_data\_length}) + \text{payload\_len}$

Then, it is determined whether PES\_extension\_flag is "1" (S183). If PES\_extension\_flag is "1", P\_STD\_buffer\_flag is set to 1 (S184). Then it is determined whether the audio data is AC-3 audio (S185). If the audio data is AC-3 audio, the two bytes following

10 PES\_extension\_flag\_2 is set to a predetermined value (0x603A) (S186). If the audio data is not AC-3 audio, the two bytes following PES\_extension\_flag\_2 is set to a predetermined value (0x4020) (S187).

The audio PES packet non-leading process is described with reference to Fig. 77B.

15 It is determined whether stream\_id is "0xBD", that is, whether the audio data is AC-3 audio (S191). If stream\_id is "0xBD", PES packet header is set to a provisional value (0x000001BD0000800004FFFFFFFF) (S192). Then PES\_packet\_length is set to a value determined by the following equation (S193).

20  $\text{PES\_packet\_length} = 7 + \text{payload\_len}$

If stream\_id is not "0xBD", It is determined whether stream\_id is "0xC0", that is, whether the audio data is MPEG-1 primary audio (S194). If the audio data is MPEG-1 primary audio, PES packet header is set to a provisional value (0x000001C00000800000) (S195). If not MPEG-1 primary audio, PES packet header is set to a provisional value (0x000001C10000800000) (S196). Then PES\_packet\_length is set to a value determined by the following equation (S197).

$$\text{PES\_packet\_length} = 3 + \text{payload\_len}$$

30 The payload process is described with reference to the

flow chart in Fig. 78.

Variable *i* is set first (S121), and the payload data of the PES packet stored to the *i*-th TS packet is read (S122). The payload data of the PES packet stored to the *i*-th TS packet is then  
5 added to the payload of the pack (S123) and variable *i* is incremented (S124). These steps repeat until variable *i* is greater than 12 (S125). That is, this process repeats until all TS packets contained in one Multiplexing Unit are processed (S122 to S125).

10 The padding packet process is described with reference to the flow chart in Fig. 79.

Whether the PES\_packet\_length is set to 2028 is determined (S131). If PES\_packet\_length is not 2028, PES\_packet\_length of the padding packet is set to  $\{(2028 - \text{PES\_packet\_length}) - 6\}$  (S132), and padding packets are added after  
15 the payload (S133).

PTS described in PES packet of MPEG-2 converted in the manner as explained above can be set with reference to PES packet header appearing first in Multiplexing Unit (see Figs. 83A and 83B).

20 Furthermore, because the PES\_packet\_length indicating the length of the video PES packet is set to 0 above, there is a problem that the PES\_packet\_length of the packet header after conversion to a pack cannot be determined until data writing to the pack completes. The PES\_packet\_length for each video PES packet in  
25 the SESEF capsule can be written to the Tip packet. The PES\_packet\_length can therefore be determined by sequential processing of TS packet units, and conversion can proceed even more quickly.

30 Furthermore, the pack header (SCR) is described above as calculated during TS2PS conversion, but the pack header can be

previously stored to the PES packet header stored in the MPEG\_TS.  
For example, the pack header after TS2PS conversion could be stored  
to the PES packet header with a pack\_header\_field\_flag in the PES  
packet header set to 1b. The data stored to the pack storing the  
5 pack header includes the data stored in packets from the TS packet  
to a TS packet determined by a specific rule (for example, a  
specific number to TS packets).

(Constraint of Video Picture in Continuous STC Section)

10 As shown in Fig. 84A, in a continuous STC (system target  
decoder reference time clock) section, a video picture (Pf) which is  
presented first in the first complete SESF capsule may be a top  
field, and a video picture (Pl) which is presented last in the last  
complete SESF capsule may be a bottom field. Fig. 84B shows a case  
15 not satisfying this rule, in which a video picture (Pf) which is  
presented first in the first complete SESF capsule is a bottom field,  
while a video picture (Pl) which is presented last in the last  
complete SESF capsule is a top field. The reason why a manner of  
presenting video picture is constrained as described above in a  
20 continuous section of a complete SESF capsule is because re-encoding  
of video stream on conversion of DVD-Video into VOB (if no edition  
of recorded stream occurs) can be prevented. This is because DVD  
standard requires that video data in one VOB is reproduced starting  
at the top field and ending at the bottom field.

25 The above constraint is one of constraints of the  
constrained SESF, and thus it is possible to judge if the above  
constraint is satisfied by referring to encode\_condition flag. That  
is, reference of this flag makes it possible to judge that, in a  
continuous STC section, a video picture which is presented first in  
30 the first complete SESF capsule is a top field and a video picture

which is presented last in the last complete SESF capsule is a bottom field.

Fig. 85 is a flowchart of recording process according to the constrained SESF provided with the above constraint.

5 First, generation of a continuous STC is started (S201). Next, a value of preset encode\_condition is acquired (S202). The value of encode\_condition is set in advance at an initial setting for user and recorder, and so on. It is determined whether encode\_condition is "11b" (S203). When encode\_condition is "11b"  
10 (recording in DVD-Video mode), it is determined whether the first complete SESF Capsule is being encoded (S208). When the first complete SESF Capsule is being encoded, encoding process is done so that a picture to be presented first in the first complete SESF Capsule is a top field (S209). Subsequently, the data is encoded as  
15 the constrained SESF to satisfy requirements for encode\_condition which is "11b" (S210).

When encode\_condition is "01b" (recording in DVD-Video Recording mode), the data is encoded as the constrained SESF to satisfy requirements for encode\_condition which is "01b" (S204).

20 Subsequently, time map information is updated every time the SESF Capsule is completed (S205). It is determined whether the recording ends (S206). When the recording ends, an end recording process is performed (S207). Until the recording ends, the above steps S203 to S205 are repeated.

25 The end recording process is described with reference to Fig. 86.

It is determined whether encode\_condition is "11b" (S211). When encode\_condition is "11b", it is determined whether a picture to be presented last in the last complete SESF Capsule is a  
30 bottom picture (S212). When the picture is not a bottom picture,



encoding process is performed so that new SESF is generated or SESF which is being encoded is completed and that the picture presented last is a bottom picture (S213).

5       When encode\_condition is not "11b", the last SESF capsule to satisfy requirements for encode\_condition which is "01b" is generated (encoding is terminated) (S214).

Subsequently, time map information is completed and recorded in the recording medium (S215).

10       Although in the above description, inverse conversion from MPEG-PS to MPEG-TS is not described, it can be similarly considered as inversion of TS2PS conversion.

15       For example, it can be considered that one PS pack is converted to a plurality of continuous TS packets, increment of ATS between the plurality of continuous TS packets is fixed value, and such information is stored in a disk or stream.

When titles of clips of MPEG-PS (program information indicating contents, etc.) are stored in SIT packet and are converted to MPEG-TS, it becomes possible to display original program titles by a decoder such as STB.

20       When self-encoding externally input AV data to an MPEG transport stream format, the data recording apparatus and method of the invention described above can thus efficiently encode and decode the streams while maintaining decoder compatibility.

25       Furthermore, because user private data can be stored to the streams recorded to the data recording medium, the added value of recorded content in the MPEG transport stream format can be increased.

30       Moreover, because the stream is multiplexed in block units of 2 KB or less so that an MPEG\_TS recorded to a data recording medium can be efficiently and easily converted to an

MPEG\_PS, the MPEG\_TS can be very easily converted to an MPEG\_PS without considering buffer management.

5 It is understood that the data processing according to the present invention described above can be achieved by a computer executing specific programs. The programs can be stored in an information recording medium readable from the computer such as floppy disk, hard disk, and CD-ROM.

10 Although the present invention has been described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims,  
15 unless they depart therefrom. The present disclosure relates to subject matter contained in Japanese Patent Application No. 2003-106399, filed on April 10, 2003, which is expressly incorporated herein by reference in its entirety.